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REDUCING C130E HERCULES OPERATING COSTS IN THE ROYAL AUSTRALIAN AIR FORCE AND THE UNITED STATES AIR FORCE BY INCREASING CRUISE SPEEDS

THESIS

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THESIS

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Abstract

The purpose of this research study was to examine a proposal to reduce C130E Hercules operating costs in the Royal Australian Air Force (RAAF) and the United States Air Force (USAF) by increasing cruise speeds. The current fuel conservation policies in the RAAF and USAF do not consider the effect of the policy on aircraft operating costs.

RAAF C130E cost data were found to be invalid. The study quantified major differences in the depot servicing, contract servicing, and in-house servicing for RAAF C130E and C130H Hercules aircraft. The study suggests that the RAAF should improve the accuracy of C130E cost data to allow a valid assessment of the operating costs over the aircraft life cycle.

USAF C130E cost data was readily divided into fixed and variable costs. The variable maintenance costs were found to be more than double the hourly fuel costs. Flight Manual data and mission profile data were used to show that the USAF could save $94,613 to $1,979,227(US) in 1989 by flying selected missions at 290 knots instead of 280 knots true airspeed (TAS). The midpoint of the calculated savings is $12.58(US) per flying hour which represents USAF savings of $1,027,017(US) per year for 1989 cost factors.

The Lockheed MACPLAN computer flight plan system was used to verify the theoretical calculations. Savings of

$5.17(US) to $15.18(US) per flying hour were demonstrated using 290 knots TAS over short and long range missions with varying payloads. The sensitivity of the calculated savings to changes in fuel and maintenance prices was also examined.

The study concludes that USAF C130E operating costs can be reduced by increasing cruise speeds. The study recommends that the USAF introduce 290 knots TAS cruise procedures immediately because of the reduction in operating costs and because there are no implementation costs.

REDUCING C130E HERCULES OPERATING COSTS IN THE ROYAL AUSTRALIAN AIR FORCE AND THE UNITED STATES AIR FORCE BY INCREASING CRUISE SPEEDS

I. Introduction

Overview

This study examines a proposal to reduce the operating costs of C130E Hercules aircraft in the Royal Australian Air Force and the United States Air Force by increasing cruise speeds. The proposal would result in payloads being delivered to their destination in a shorter time and at a reduced cost.

Since the world oil crisis in 1973, the Royal Australian Air Force (RAAF) and the United States Air Force (USAF) C130E Hercules squadrons have conserved fuel by cruising at a true airspeed (TAS) of 280 knots. The C130E aircraft are now 16 years older and the relative importance of fuel costs and maintenance costs may have changed considerably. This study analyses the current C130E operating costs for the 280 knots TAS cruise policy. Current costs are then compared to the operating costs for faster cruise speeds. This comparison is used to show that C130E cruise speeds can be reduced by increasing the cruise speed above 280 knots TAS.

This chapter outlines the major roles of the C130E Hercules within the RAAF and the USAF. Current C130E Hercules operating policies within RAAF and USAF are then described. This is the foundation for a statement of the purpose of the study and the investigative questions which were used to form the study framework.

Terminology. Terms used within this study are defined in Appendix A. National currency is abbreviated within this study as follows: American dollars \$(US), Australian dollars \$(AUS), and Canadian dollars \$(CAN). References to gallons in this paper always describe American gallons.

The Mission of the C130E Hercules

The C130 Hercules is a four-engined turbopropeller, transport aircraft used in more than fifty countries around the world. Over 1,700 Hercules aircraft have been built for use in many different types of military and civilian missions such as cargo transport, medical evacuation, search and rescue, combat operations and passenger transport(39:1). Each type of mission has a different rate fuel consumption and different sortie length (55:2-9). Analysis of RAAF and USAF C130E operating policies and cost performance should therefore take cognizance of major differences in the utilization of the aircraft by the two services.

C130E Mission in the RAAF. The Royal Australian Air Force (RAAF) operates 12 C130E and 12 C130H Hercules aircraft. They are used in support of the Australian Defence Forces and in support of the civilian community when required by the government. The range of these missions varies from about 30 miles to over 3,000 miles. The primary mission of the C130E Hercules in the RAAF is strategic (long range) transport. Low level, tactical and airdrop missions are the responsibility of the C130H transport squadron (41).

C130E Mission in the USAF. The USAF operates 244 C130E aircraft and 148 C130H aircraft (6). The USAF does not divide the roles of the Hercules aircraft in the same manner as the RAAF. All operational C130 squadrons in the USAF can be involved in a combination of tactical and long range transport missions (50).

Current C130E Hercules Operating Policies

In 1973, the Organization of Petroleum Exporting Countries (OPEC) increased the price of oil to the world community. As a result, the price of aviation fuel increased from $0.113(US) per gallon to $0.352(US) per gallon (6). This was the first of many increases made over the following decade. The price paid by the USAF for aviation fuel peaked in 1982 at $1.31(US) per gallon and has decreased over recent years to $0.61(US) per gallon in 1989 (6).

In the commercial aviation industry, the concern over fuel costs reflected the increases in OPEC prices. The price of fuel was 10 percent of direct operating costs in 1973 and increased to 30 percent of operating costs in 1981 (38:148). The reaction of most civil and military aircraft operators to the rapid increase in the price of aviation fuel was predictable. Policies which minimized the use of fuel were evaluated and introduced. Studies by the United

States Department of Energy, Civil Aeronautics Bureau, and the United States Air Force considered a multitude of methods for saving fuel (9;25;29;30;38;49).

One method of saving fuel considered in the literature was to operate the aircraft at the speed which resulted in the maximum range for each pound of fuel used (29;30;49). The three major users of C130E Hercules transport aircraft (USAF, Canadian Forces and the RAAF) decided independently to operate their C130E aircraft at a speed of 280 knots true air speed (TAS) to save fuel (23;41;57).

In 1981, the Canadian Forces evaluated their C130E Hercules operating policies and included the effect of other operating costs such as maintenance. Maintenance costs were in the order of 60 to 70 percent of total operating costs at that time (23:1). When the relative importance of all cost components was considered, this Canadian research appeared to indicate that the fuel saving policies for C130E Hercules aircraft added to the total operating costs: each dollar in fuel saved was adding almost two dollars to the aircraft maintenance costs (23:2). Therefore, the Canadians introduced a policy which emphasized a reduction in the number of flying hours by flying the C130E faster, instead of flying slower to save fuel (23;35).

In contrast to the Canadian policy of saving flight time, the C130E Hercules squadrons of both the RAAF and USAF have maintained policies which are directed at minimizing fuel costs. This study analyses the costs for these two different operating policies.

Purpose of the Study

This study analyses the current policies within the RAAF and the USAF for cruise operations of C130E Hercules aircraft. This analysis is used to test the hypothesis: Variable operating costs of RAAF and USAF C130E Hercules aircraft can be reduced by increasing the cruise speed above the current normal speed of 280 knots.

Investigative Questions

The following questions were investigated during this study:

1. In civil and military organizations which use C130E Hercules aircraft, what are the current policies which relate to minimizing operating costs?
2. What are the cost components for operating a C130E Hercules?
3. What was the validity of Canadian research which recommended that C130E aircraft be flown at faster speeds than those used in the RAAF and USAF?
4. Do current fuel economy policies really save money?
5. Using current operating costs, can a variation in operating speeds be proposed which results in a reduction in total operating costs?

6. Can a flexible operating policy be proposed which accounts for major variations in the cost of one component such as fuel?

7. Can any proposed policy change be easily implemented through the incorporation of algorithms into the flight planning computers?

Scope and Limitations

The analysis in this study is limited to the cruise portion of flight for the C130E model Hercules. Extension of conclusions and recommendations to other types of C130 Hercules should not be made without a study of that specific type of aircraft's operating cost structure.

Direct comparisons should not be made between any C130E Hercules operating costs in the RAAF and USAF which appear to be equivalent. Each military service utilizes different methods of accounting for direct and indirect operating costs. Other factors, such as flying rates, type of missions, weather and aircraft modifications, could influence the cost of operating aircraft within a country.

The study will not consider increasing current engine power settings to achieve higher cruise speeds. Increasing the power settings may increase the cruise speed but the increased power may be at the expense of engine life and increased maintenance costs (52:5-8;41:5-2). The calculations made in this study have been made on the premise of maintaining the current normal cruise power settings at a lower altitude where a higher cruise speed can be maintained. At the lower altitude a higher cruise speed is therefore achieved with an increase in fuel consumption but without any detriment to maintenance costs.

Assumptions

The cost data supplied by the Director of Costing in Australia and the Air Force Cost Center in the United States are assumed to be accurate. These data provide the yardstick for analysis within each country. The validity of this assumption is examined in Chapter IV.

The Lockheed flight planning computer is assumed to accurately predict C130E Hercules performance characteristics such as cruising altitude, range, cruising speed, fuel consumption and the duration of a flight.

The aim of C130E Hercules operating procedures in the RAAF and USAF is to meet the mission requirements at minimum total cost. Therefore, conservation of fuel, for the sole reason of conserving a resource, is not treated as a limiting criterion of operations in this study.

Organization of this Study

This study is presented in six major sections. Chapter I outlines the background to current C130E Hercules operating policies in the RAAF and in the USAF and then outlines the reason for this study. Chapter II reviews previous research about direct operating costs for military and civilian aircraft. The methodology used to prove the study hypothesis is described in Chapter III. The analyses of C130E operating costs and mission profiles in the RAAF and the USAF is reported in Chapter IV. This research is the foundation for analysis, in Chapter V, of the affect of cruise speeds on operating costs and the implementation of higher cruise speeds. The conclusions and recommendations which result from this study are detailed in Chapter VI.

II. Literature Review

Overview

A description of the RAAF and USAF regulations which affect the operating cost of the C130E Hercules is the initial point of reference for this literature review. Civilian and military research on aircraft operating costs since 1973 are then reviewed chronologically. The research describing aircraft operating cost models is then reviewed. Finally a Canadian research paper on operating policy for the Canadian Forces' C130E aircraft is analyzed. Weaknesses are identified in the validity of each study. Further analysis in Chapters IV and V is therefore required to consider the operating costs of C130E Hercules aircraft and the effect of cruise speed on operating costs.

RAAF Operating Regulations

RAAF regulations do not appear to give any guidance to C130 Hercules aircrew about minimizing the total cost of aircraft operations. The fuel cost is considered indirectly through fuel conservation policies (41:2-409). C130 Hercules Standard Operating Procedures require aircrew to conserve fuel by flying the C130E Hercules at a speed of 280 knots (41:2-409). Aircrews are directed to "adopt fuel conservation practices appropriate to the circumstances at the time/stage of flight" (41:2-409). These policies appear to be directed at conserving the fuel resource and do not appear to consider the relative costs of fuel and maintenance on total operating costs.

USAF Operating Regulations

USAF regulations appear to be directed towards fuel conservation. The C130E cruise speed of 280 knots TAS was introduced after the first world oil crisis in 1973 (50). C130E fuel planning is required to be in accordance with the Flight Manual and Military Airlift Command Regulation (MACR) 55-19 (57:7,8). These orders include a range of cruise speeds from 220 to 300 knots TAS, but do not require any specific cruise speed to be used (52). The practice within MAC is for almost all flights to be flown at 280 knots TAS (57). All of the examples of flight planning procedures in MACR 55-130 use a cruise speed of 280 knots TAS (57:11-6,11-27,11-38,A11-1-2,A11-2-4). This speed is also the default cruise speed in the MAC flight planning computer (17). Scope is given for the aircraft to be flown at 290 knots when "mission directed," but this direction "occurs infrequently" (50). Some MAC navigator and medical evacuation training missions are flown at speeds of 245 or 260 knots. These training missions are flown for a fixed duration and therefore are flown at fuel conserving speeds (50).

The one guiding statement to USAF aircrew about the selection of cruise speeds states that "the particular cruise schedule must be selected to maximize or minimize the parameter that will assure the most efficient completion of the mission" (52:5-8). Operating costs could be included as one of the parameters, but there does not appear to be any mention of operating costs to USAF aircrew (50;52;56;57).

Save Costs by Saving Fuel

In 1975, Stengel and Marcus studied C-141A Starlifter fuel conservation through the use of energy management. They proposed that an optimal flight path should meet the mission requirements at minimal cost (49:464-465). They noted that it was common for the cruise segments of a flight to be flown one or two per cent faster than the speed designated as the maximum range speed. One reason advanced for this technique is the reduction of time related costs (49:465). The theory of this technique is that, for a small increase in fuel consumption, an aircraft can be flown at a faster speed and reach its destination in a reduced number of flying hours. The cost of the extra fuel is recovered through the reduced flying hours (9:267). Stengel and Marcus proposed that the price of fuel was so high in 1975 that any cost saving by flying faster than fuel conserving cruise speeds "may be negligible" (49:465). However, no evidence was provided to support this proposal.

In 1978 the Dynamics Research Corporation completed a major study of fuel conservation in the United States Air Force (29;30). This study quantified possible improvements in operational procedures and aircraft structures which would reduce USAF fuel consumption for the B-52G, the B-52H, KC-135, the C-141, the C130E and the C-5A. The authors address "a controversy in literature about the optimality of cruise" (30:1-3). The optimum cruise, in this report, is one which minimizes the quantity of fuel used (30:3-24). Mathematical formulae are derived for the energy requirements for minimum fuel. These formulae are applied to the C-5A Galaxy and C141 Starlifter (30:B1-B12). The results of this two-aircraft study are used to make a general conclusion for all aircraft in the study: "Since these two aircraft are representative of the aircraft under study, it is most likely that the steady state cruise is optimal for all aircraft under study" (30:3-24). This generalization could be criticized because the two aircraft used to represent the other aircraft in the study were jet-engined aircraft and may have considerably different performance characteristics than those of the C130E, which is powered by turbo-propeller engines. The report recommended that the USAF C130E Hercules be flown at the maximum range speed of about 265 knots (30:7-144). Fuel savings of 5.2 per cent were estimated to result from this change in policy (30:7-175). The USAF does not appear to have implemented the report's recommendation in regard to C130E Hercules cruise speeds because 280 knots TAS has continued to be the normal C130E cruise speed (50).

Save Costs by Saving Flight Time

At the symposium on Commercial Aviation Energy Conservation Strategies in 1981, D. Ferguson, of Eastern Airlines, proposed that aircraft operating costs could be saved by flying faster to save flight time (9). He acknowledged that fuel could be saved by flying aircraft at slower speeds. However, he noted that there were "economic penalties" such as additional maintenance, crew costs and lost revenue which resulted when this fuel saving policy was pursued to "its ultimate limit" (9:260). Slower speeds increase the flight time; therefore, the direct costs, which are calculated at an hourly rate, are higher. Ferguson noted that high fuel costs had caused most airlines to abandon the minimum cost method of cruising, in favour of a cruise which conserved fuel (9:263). According to Ferguson, "the difficulty with this approach is that it works well for the average airplane at the average weight, at the normal temperature, in the no wind case, but not everywhere else" (9:263). Ferguson concluded that a valid technique for saving fuel was to increase the cruise speed above the maximum range speed (9:267). He used some commercial aircraft as examples to show the potential savings from increased cruise speeds for aircraft which have relatively small changes in range with changing airspeed (9:267). The C130E Hercules has a small change in range when airspeed is increased above the maximum range speed, as shown on Figure 1. Therefore, Ferguson's recommended increase in cruise speed to reduce operating costs could apply to the C130E Hercules.

Costs Vary with Aircraft Usage

In a further development of aircraft operating cost

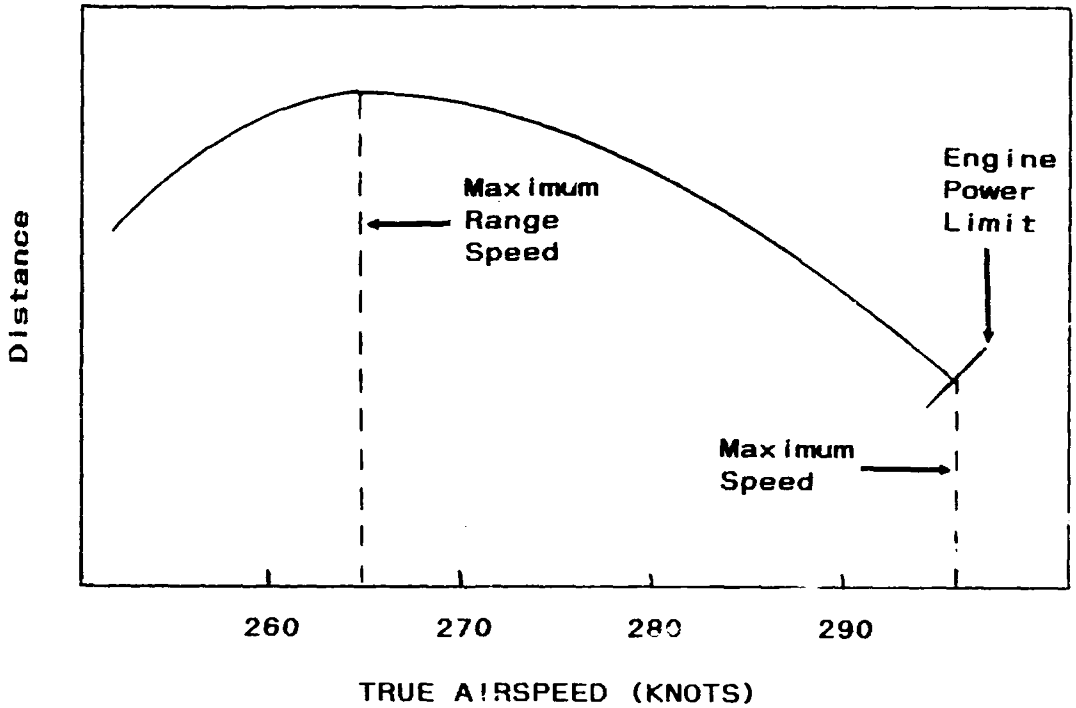


Figure 1. Schematic C130E Hercules Performance Chart

policy in 1986, McCarthy proposed that when aircraft were used for a few hours per day, the cost structure was very different from the cost structure for aircraft which flew for about 20 hours per day. He used the airfreight forwarding industry as an example of aircraft which are used for about four hours per day. Due to the low daily utilization, the fuel costs in the airfreight forwarding industry are a low proportion of the total aircraft operating costs (24:107).

It could be argued that low utilization of military transport aircraft, such as the C130 Hercules, could result in a cost structure similar to the airfreight forwarding industry. USAF and RAAF C130E aircraft are flown for an average of about two hours per day (6;27). The low aircraft utilization by the military was a factor in the design of the Advanced Civil/Military Aircraft (28). Lockheed noted that the military choice of aircraft is based on the "life cycle cost of the aircraft, mission effectiveness and mission flexibility" (28:6). Commercial considerations are made on the basis of "direct operating cost, indirect operating cost and the return on investment" (28:6). Civil operators were driven by the revenue earning capacity of the aircraft, whereas the military aircraft selection decision was not related to the aircraft revenue earning capacity (28:6).

Aircraft Operating Cost Models

The high utilization of civilian transport aircraft and the high cost of aircraft acquisition could be factors in the development of cost models which demonstrate the earning capacity of the aircraft (4:3-1). For example, the Civil Aeronautics Board developed the "Commuter Flight Analysis Program" to produce commercial profit data based on utilization and load density (4:3-1). These models are not helpful for examining the cost of military aircraft because military utilization of aircraft is low and because the transport of military passengers and cargo is not necessarily done on a revenue-earning basis. The two following cost models for C130 aircraft were considered for use in this study.

Dynamics Research Corporation Cost Model. In 1978, Dynamics Research Corporation developed a cost model for the C130E Hercules (29;30). The validity of this model may be criticized for the maintenance cost calculations, the use of the mission profile data, and the methodology for estimating variable costs.

Maintenance Costs. The report uses the "Increase[d] Reliability Operational System" (IROS) for estimating the direct maintenance costs of C130E aircraft (30:2-13). "Due to the fact that certain base level costs for unscheduled maintenance and certain depot costs were not included in the IROS data," this study doubled the IROS figures so that they would be more "realistic" (30:2-14). The decision to double the IROS data "was based on published information" (30:2-14). Unfortunately, the source was not given.

Mission Profile Data. The study used mission profiles from the Aircraft Structural Integrity Management Information System. The data used in the study has questionable validity. Data from two months of C130E flying were extracted to represent all C130E flights (30:3-26,7-130). Using only two months of data can distort the mission profile data. For example, the monthly flying hours for MAC C130E between January 1988 and May 1989 varied between 1200 hours and 1700 hours. During the same period, the percentage of flights flown on the type of missions used in the Dynamic Research Corporation study varied from 37 percent to 52 percent of the total flying hours (13). A longer time period might have removed small variations which could occur in monthly data.

Estimation of Variable Costs. The methodology used by Dynamics Research Corporation was to use models where 25, 50, 75, and 100 percent of maintenance and crew costs were considered to be related to time. These models do show a range of costs and it may be possible to estimate costs by interpolating between the models. However, cost information available today distinguishes between "fixed costs," which are not related to flight time, and "variable costs," which change with flight time. Therefore, it may be possible to develop more accurate models of operating costs using current costing methods.

Lockheed Study of RAAF C130E Costs. In May 1988, Lockheed published a report which evaluated the cost effectiveness of the RAAF C130E Hercules aircraft. Cost data in the report were gathered in Australia in April and May 1987 during discussions with RAAF personnel and the RAAF C130E civilian contractor (22:21). The methodology within this report distinguishes between fixed and variable costs (22:24). Any question about the validity of this report lies not in the methodology but in the source data. The validity of RAAF C130E cost data is analyzed in Chapter IV.

Canadian Forces C130 Hercules Research

Overview. The Canadian Forces C130 Hercules operators endorse the concept of saving operating costs by saving flight time (23;35;51). In 1981, the Canadian C130 Hercules squadrons changed from using a long range cruise policy which conserved fuel to a minimum time for fuel available (MTFA) cruise which minimized flight time (35:1). A study compared the total cost of flying the C130 Hercules at the long range cruise airspeed with the total cost when the aircraft was flown at a speed to minimize the flight time (23). In the study, calculations showed that the long range cruise was saving the Canadians $5,200(CAN) per aircraft per month in fuel costs (23:2). This saving was achieved by flying at a slow speed but increased the length of flights. The additional flight time cost $11,850(CAN) (23:2). It was costing $11,850(CAN) in direct operating costs to save $5,200(CAN) in fuel costs (23:2). The Canadian Forces changed their policy and began to fly their C130 Hercules aircraft at MTFA to minimize flight time and reduce total operating costs (35;43). This policy was endorsed again in 1988 after fuel prices had reduced to a "moderate level" (51). Serious doubts about the internal and external integrity of the Canadian study are detailed in the following analysis.

<u>MTFA Causes Decreased Sortie Length</u>. The unstated assumption in the Canadian study is that the MTFA cruise technique is the only cause of the change in sortie length during the study. The study compared the average sortie length for the Canadian C130 fleet, when using MTFA techniques to reduce sortie length, with the sortie length when the aircraft were flown using long range cruise

techniques to conserve fuel. The average sortie length was calculated to be 0.2 hours shorter when MTFA cruise techniques were used (23:1). No other possible causes for the change in sortie length were considered. However, a number of external factors could have been considered. These factors include possible changes to the C130E mission during the study period, and the possibility that removing the external fuel tanks from the aircraft may have caused more refueling stops and therefore caused shorter sortie lengths.

<u>Removing External Fuel Tanks</u>. External fuel tanks were removed from some of the 28 Canadian C130 Hercules aircraft during the study period and this could be a significant moderating factor. Up to 23 C130 aircraft had their external tanks removed while the aircraft were being flown using MTFA techniques, but all tanks were replaced on the aircraft for at least five months of the long range cruise part of the study (23:4). The effects of removing the external fuel tanks include a decrease in aircraft weight and a decrease in aircraft drag (42:1-1;52:1-2). The Canadian study suggests that there was a trend towards higher fuel consumption with the external fuel tanks removed. An increase in fuel consumption is contrary to the C130E Flight Manual, which shows that one effect of removing the external fuel tanks is the ability for the aircraft to cruise 800 feet higher (42:5-8). Cruising 800 feet higher results in a decreased fuel consumption of about 100 pounds

per hour (42:2-5). Another effect of removing the external tanks is that the aircraft can fly 4 knots faster true air speed, which would have reduced the sortie length (42:5-31). The removal of the external fuel tanks during the study is therefore a significant moderating factor and raises doubt about the internal validity of the Canadian study.

Average Monthly Fuel Consumption. The validity of using average monthly fuel consumption in the Canadian study could be questioned. Monthly fuel consumption during the study appears to vary on a 12 month cycle with the lowest average fuel consumption being about 550 gallons per hour in July and a peak in fuel consumption being over 610 gallons per hour in April each year (23:4). The study states that while the long range cruise technique was being used, average fuel consumption per month was 573 gallons per hour (23:2). Fuel consumption increased to 590 gallons per hour when the MTFA cruise was used (23:2). These average figures were derived by averaging the monthly average fuel consumption. A major problem with this technique is that a month with few flying hours is weighted more than a month with more flying hours. A better technique may have been to relate monthly fuel averages and flying hours, and to consider the effect of the type of cruise over a 12 month period using the total fuel consumption.

Aggregating Results. Aggregation of fuel and maintenance costs for different model C130 aircraft could affect the accuracy of the study results. The data used in the Canadian study was obtained for the C130 Hercules "fleet" which was a mixture of C130E and C130H model Hercules (23:1,2). No attempt was made in the study to differentiate between the two types of Hercules aircraft. The USAF uses an average fuel consumption of 763 gallons per hour for the C130E and 824 gallons per hour for the C130H (55:2-5). Therefore, the type of C130 aircraft has a considerable effect on the quantity of fuel consumed. Similarly, the maintenance costs for the two types of C130 vary considerably (11). The USAF uses $978(US) per flying hour for C130E direct operating costs excluding fuel, and only $833(US) for the C130H Hercules (55:2-5).

Generalized Benefits of MTFA. The benefits of the Canadian study may have been exaggerated by extension of the benefits to every type of mission for both types of C130 (23:2,3). Training, formation, and low level flying are three examples of missions where the use of MTFA techniques in the C130 Hercules could be considered unlikely. The Canadian study does not refer to any missions in which the benefits of MTFA were not achievable.

Conclusion

RAAF and USAF C130E Hercules operating regulations appear to be directed at minimizing fuel costs through conservation of fuel. The impact of maintenance costs on total operating costs does not appear to be considered. According to Ferguson, a policy which aims to minimize fuel costs may not minimize total operational costs (9:20).

After the price of aviation fuel increased over 350 per cent in 1973, civil and military cost literature focused on minimizing fuel costs. Stengel and Marcus proposed in 1976 that the cost saving which resulted from flying an aircraft faster than the maximum range speed "may be negligible" because of the high cost of fuel (49:465). However, no empirical evidence was provided to support this proposal. The Dynamics Research Corporation report in 1978 concluded that USAF C130E aircraft should be flown at 265 knots TAS to conserve fuel (30:7-144). The report assumed that the cost structures for all aircraft in the study were the same as the cost structures of the jet-engined B52 bomber and C141 Starlifter. The C130E Hercules has turbo-propeller engines and therefore the cost structure may be different from the other aircraft in the study.

Analysis by McCarthy and by Lockheed indicated that aircraft utilization affects the cost structure (24;28). The utilization of the C130E Hercules by the RAAF and USAF could be compared to the utilization of aircraft in the freight forwarding industry. In that industry, fuel costs are not considered as important as other operating costs (24:107).

Ferguson disagreed with the emphasis on fuel saving policies in 1981. He recommended that cruise speeds be chosen to minimize total costs rather than minimize fuel costs (9:260). A Canadian Forces study showed that for the C130 Hercules, the fuel conserving policies were costing more than twice the value of the fuel saved (23:2). Canadian C130 Hercules aircraft were ordered to fly at a faster speed and minimize direct operating costs (43). However, the validity of the Canadian study should be considered. These considerations include: the assumption that Minimum Time for Fuel Available cruise was the only cause of reduced sortie length; the removal of the external fuel tanks during the study may have influenced the results; the use of average monthly fuel consumption may have biassed the results; the effect of aggregating results for different model C130 aircraft was not considered; and the generalization of benefits to all C130 Hercules sorties, regardless of mission, may not be valid.

Civilian aircraft cost models emphasize the revenue earning capacity and the return on investment available from an aircraft. These considerations are not part of military cost models. A Dynamics Research Corporation cost model for USAF C130E aircraft has questionable validity because of the manipulation of maintenance costs; the arbitrary allocation of time related costs and the use of a two month sample of mission profile data which may not portray the real mission spectrum over a longer period. Lockheed's study of RAAF C130E costs is only as good as the data supplied by the RAAF. The validity of this data is examined in Chapter IV.

Further analysis is therefore required to consider the direct operating costs for the C130E Hercules over a variety of airspeed and time combinations in each of the aircraft's missions. This analysis is provided in Chapters IV and V.

III. Methodology

Introduction

The primary goal of this study is to determine if the C130E Hercules operating costs can be reduced by increasing the cruise speed from the current 280 knots TAS. This goal was achieved by defining the variable operating costs for a C130E aircraft at 280 knots TAS and then comparing the costs at other cruise speeds. The results of this comparison were then used to recommend a C130E cruise speed which reduced operating costs. The findings of this study are intended for direct application by C130E aircrews. Therefore an important goal of this study is that any proposed changes to C130E cruise speeds be based on proven flight manual data and that the recommended cruise speed be implemented easily (26). The study achieved these goals in seven phases.

Phase One: Investigation

In the first phase of research, a review of available literature was used to address four specific investigative questions. These questions were:

1. In civil and military organizations which use C130E Hercules aircraft, what are the current policies which relate to minimizing operating costs?
2. What cost models, if any, are available which could assist with developing a cost algorithm for the C130E Hercules?

3. What was the validity of Canadian research which rec mmended that C130E aircraft be flown at faster speeds than those used in the RAAF and USAF?

4. What are the cost components for operating a C130E Hercules?

Military C130E Hercules Operators. The three major users of C130E Hercules aircraft are the Canadian Forces, the RAAF, and the USAF (39). The current C130E Hercules operating policies were readily obtained from each nation's regulations (41;57). The United States Defense Technical Information Center (DTIC) sources were searched for any past C130E Hercules studies. This initial search was then expanded to include operating policies and analysis of aircraft operating costs for all aircraft. The 4950th Test Wing in the USAF Aeronautical Systems Division, Lockheed Dataplan, and Lockheed Aeronautical Systems Company were the source of additional research reports. Searches were restricted to reports published after 1973, when the oil crisis changed the structure of aircraft operating costs and increased the interest in operating policies and cost saving techniques.

Civilian C130 Hercules Operators. There are only two civilian users of C130 Hercules aircraft. Southern Air operates 17 C130 aircraft from its base in Miami, Florida, and Mark Air operates three C130 aircraft from a base in Anchorage, Alaska. All of these aircraft are L382G model Hercules which have more powerful engines and are larger in size than the C130E Hercules (39:111). Despite these differences, these two operators were included in the study. It was anticipated that the profit motive, inherent in civilian activities, would have created some unique insight into operating Hercules aircraft to minimize total operating costs. Information about the operating policies of each company was obtained using telephone interviews with the companies' chief C130 Hercules pilots. In an unstructured interview, each chief pilot was asked to describe the cruise control policies for C130 aircraft within his company. Any differences between the company policies and military policies were then identified and discussed. Each chief pilot was then asked about the influence of direct cost components such as fuel and maintenance on operating policies.

Civilian Research. The large airlines' wealth of experience in minimizing total operating costs could not be ignored in this study, despite the differences between operating civilian jet aircraft and military turbo propeller aircraft, such as the C130 Hercules. Dialog Information Services was used to search International Aerospace Abstracts for available studies on operating cost policies and procedures, outside of the military environment. This search was conducted despite the obvious limitation of commercial aviation companies being unwilling to divulge proprietary information to competitors.

Canadian Research. The Canadian research in 1981 about C130E operating costs and cruise speeds represented an important parallel research to this study (23). The source data used in Canadian research was obtained from the No 426(T) C130 Hercules Training Squadron (36). The methodology, validity and limitations of the Canadian research, and its conclusions, were then clearly identified.

Cost Data. The agencies responsible for cost data in Australia and the United States were requested to supply data on C130E Hercules operating costs. Each country's data were then analyzed. The purpose of the cost data and the methodology for data collection were examined. Variations in accounting techniques for fixed and variable costs within the data were established. The impact of different cruise speeds on aircraft operating costs could then be derived in terms of the affect on variable operating costs.

Phase Two: Selection of Mission Profiles

In phase two, the C130E missions which could normally be flown at 280 knots TAS or higher were defined. The spectrum of C130E missions was obtained from the aircraft's structural integrity statement (5;37). This statement summarizes the flights of every C130E aircraft and groups them according to the affect of each flight on the structural life of the aircraft. This data base is updated continuously and is used by the air forces in each country to establish representative mission profiles (5;37). RAAF and USAF Mission Profile Analysis data was used to select the percentage of missions which could be flown at increased cruise speeds.

Phase Three: Testing the Hypothesis

The hypothesis that increasing C130E cruise speeds above 280 knots TAS could reduce operating costs was tested in phase three. The C130 Performance Manual was used to obtain data on the fuel consumption at specific aircraft weights, altitudes, and true airspeeds. The effect of cruising at 260, 280, and 290 knots TAS on operating costs was calculated using the Performance Manual fuel consumption data and the cost relationships from phase one. The difference between operating costs at 280 and 290 knots TAS was calculated to be the savings from the higher cruise speed. The product of the hourly savings in operating costs and the missions defined in phase two was then used to estimate annual savings which could be achieved at the higher TAS. The accuracy of the potential savings was estimated using the accuracy of each component in the calculations.

The sensitivity of the savings to changes in fuel prices was then examined. In this study, increased cruise speeds are used to reduce flight time and variable maintenance costs, but these speeds are achieved by increased fuel consumption. If the price of fuel increased, the decrease in maintenance costs could equal the increase in fuel costs. The fuel price at this break even point was calculated by considering maintenance costs to be constant.

Phase Four: Demonstration of Variation in Operating Costs

The validity of the mathematical calculations in phase three was then demonstrated using Lockheed's computer flight planning system. The flight planning computer has C130E Hercules performance data stored for daily use by the RAAF and USAF aircrews. The assistance of the Lockheed Dataplan Customer Services Department was obtained for the submission of flight plans. The computer allows dynamic variations of aircraft weight and altitude over the duration of a flight. A range of feasible missions distances and aircraft weights was used to obtain data on fuel usage and flight durations, at the available speeds of 260, 280 and 290 knots TAS. The fuel usage and flight duration data were then entered into a spreadsheet. The operating cost of each flight was calculated using the 1989 cost data from phase one. A direct comparison could then be made for C130E Hercules operating costs at 260, 280, and 290 knots TAS over a range of possible aircraft payloads for different flight durations.

Phase Five: Limits on Increasing C130E Cruise Speeds

In phase five, the potential benefits of flying the C130E at speeds greater than 290 knots TAS were examined. The cost relationships established in phase one were used in calculations of possible maintenance savings at the higher speeds. Achieving the higher speed and maintenance savings requires increased fuel consumption. The hourly increase in fuel consumption which would equal the maintenance savings was calculated. The calculated increase in fuel consumption represents a break even point, beyond which the variable costs would be higher than the current 280 knots TAS cruise.

The power available from the C130E engine imposes a practical limit on cruise speed. The Performance Manual does not include data about the power available or the power required for a particular cruise speed. Lockheed Aeronautical Systems Company resources were used to produce a graph (Figure 3) which shows the maximum speed which a C130E can achieve at varying altitudes and aircraft weights using normal cruise power.

<u>Phase Six: Implementation</u>

Implementation of new cruise speeds requires that aircrew have ready access to the necessary aircraft performance data and that the computer flight planning system be programmed for the nominated speed. The availability of this data in the RAAF and USAF was investigated in phase six.

As part of the implementation process, aircrew could be made aware of the operating costs for each flight. This proposal is considered in phase six through the use of the flight planning computer and the cost equations developed in phases three and four.

Phase Seven: Conclusions and Recommendations

In the final phase of the study, conclusions are drawn and recommendations are made on implementation of higher C130E cruise speeds to reduce operating costs.

Summary

The operating costs associated with different RAAF and USAF C130E Hercules cruising speeds has been studied in seven phases. In first phase, the current regulations and policies about operating costs of military and civilian C130 Hercules operators were investigated. DTIC and Dialog searches were made of aircraft operating costs and policies since 1973. The relationship between the components of current operating costs for RAAF and USAF C130E Hercules aircraft was then established.

In the second phase, representative mission profiles were obtained from the C130E aircraft's fatigue analysis to account for the spectrum of missions. These profiles were used to estimate the missions which could be flown at airspeeds of 280 knots TAS and higher.

The hypothesis that C130E operating costs could be reduced by cruising at increased cruise speeds was tested for static conditions of weight and altitude in the third phase. The operating costs for different TAS were calculated using current cost data. Potential cost savings were calculated for the C130E cruising at 290 knots TAS instead of 280 knots TAS. The sensitivity of the cost savings to variations in fuel and maintenance prices was then calculated.

In the fourth phase, dynamic testing in the Lockheed flight planning computer was used to provide data on fuel usage and flight duration at 260, 280, and 280 knots TAS under varying conditions of aircraft weight, altitude and flight duration. A spreadsheet analysis of the flight plans enabled a direct comparison of the operating costs at each airspeed.

Practical limits on C130E TAS were examined in the fifth phase. Knowledge of these limitations is important to the implementation of higher cruise speeds which was considered in the sixth phase. In the seventh phase of the study, conclusions were drawn and recommendations were made on implementation of higher C130E cruise speeds to reduce operating costs.

IV. Analysis of Cost Data and Mission Profiles

Overview

The analysis in Chapter II of earlier research regarding C130 operating costs revealed some inaccurate cost data and inaccurate use of mission profiles to predict potential savings. This chapter will validate RAAF and USAF cost data and identify the missions which could be used in this study to estimate savings in operating costs. The research and findings are presented in four sections.

In the first section, the policies for minimizing variable operating costs by civilian C130 operators are examined for any insight which may be applied to the study of military C130 operating costs. Then, in the second and third section, the operating costs for C130E aircraft in the RAAF and the USAF are analyzed. The aim of this analysis is to validate the available cost data and distinguish between those costs which are fixed and those costs which vary with the flight duration. In the fourth section, the missions which could be flown at increased cruise speeds are identified and separated from the missions which cannot be flown at increased cruise speeds.

The research about the variable costs, which change with the flight duration, and the missions which can be flown at increased cruise speeds, is the foundation for testing the study hypothesis in Chapter V.

Section 1: Civilian C130 Hercules Operations

The L382G model Hercules is the only model of the C130 Hercules which is used commercially in the United States (39:107). This aircraft is larger and has more powerful engines than the C130E Hercules (39:84). Despite these differences, the civilian operators were included in the study because the competition of deregulated air transport could make these companies more responsive to minimizing costs than the military operators. In an unstructured telephone interview, the chief C130 Hercules pilot for each of the two civilian companies was asked to describe the cruise control policies for his company's C130 aircraft. Any differences between the company policies and military policies were then identified and discussed. Each chief pilot was then asked to describe the influence of direct cost components, such as fuel and maintenance, on operating policies within the company.

Southern Air Transport. Southern Air Transport operates 17 L382G model Hercules aircraft from a base in Miami, Florida. Southern Air is responsible for many military transport contracts, including Logair. Only one of the 17 aircraft is fitted with under wing fuel tanks because the majority of the company flights do not require extra fuel. Southern Air prefers the reduced operating costs which results from the removal of the external fuel tanks. The maximum cruising altitudes for Southern Air Hercules aircraft is 27,000 feet because of Federal Aviation

Administration certification requirements. Normally the company's C130 aircraft cruise at true airspeeds of between 280 and 300 knots TAS depending on the range and payload of the task. The Department of Defense pays for most of the company's fuel and therefore maintenance and crew costs are the primary direct operating expenses for the company (12). Company policy is to reduce maintenance costs by minimizing flight time. However, paying aircrew by the hour could have the effect of increasing flight time (15). The company uses a computer flight plan system to expedite the flight planning process, ensure flight planning accuracy, and minimize flight time. The computer is programmed to minimize flight time by using direct tracks between airfields whenever possible. The computer also evaluates the reduced flight time which could result by improved tail winds or decreased headwinds if the aircraft is flown up to 30 degrees either side of the direct track (12).

Mark Air. Mark Air operates three L382G model C130 aircraft from a base in Anchorage, Alaska. These aircraft are used primarily for carrying heavy loads over short distances. Typical operations require a take off at 142,000 pounds and a landing at 135,000 pounds. On flights which are less than one hour duration, the aircraft are usually flown at a cruising altitude of 20,000 feet. The maximum certified ceiling of the aircraft is 27,600 feet. On longer flights, the aircraft are flown at true airspeeds of 280 knots if fitted with under wing fuel tanks and 290 knots without the under wing tanks. The general operating policy of the company is to save flight time because "fuel is cheaper" (59). The company leases C130 aircraft at times. The leased aircraft are flown to minimize flying time because charges are levied at a fixed rate per flying hour. Mark Air uses a computer flight plan system similar to that of Southern Air to assist pilots and management minimize flight time (59).

Both Southern Air Transport and Mark Air place more importance on the affects of maintenance costs and flight time than on saving fuel costs. These polices are opposite to the RAAF and USAF fuel conservation policies.

The costs of operating RAAF C130E aircraft will now be validated and divided into costs which are fixed and costs which vary with flight time.

Section 2: Cost Data for RAAF C130E Aircraft

The Costing Section within the Resources and Financial Programs Division of the Australian Department of Defence calculates a standard cost per flying hour for each type of Australian military aircraft. The primary purpose of this rate is to "recover costs for the use of Defence aircraft by other departments and organizations" (47:2). The rates are also used as a basis for cost assessments for exercise approvals and are the only authoritative estimate of RAAF C130E operating costs (47:2).

Australian Costing Section Terminology

The Australian Department of Defence Costing Section uses the term "full cost" when referring to the total of "direct costs," "on costs," and "capital costs" for each flying hour (47:2,3). Terminology used by the Costing Section is defined in Appendix B. The simplified summary of key Australian costing terminology which follows, is an essential foundation for analyzing the validity of the RAAF cost data.

Direct Costs. Direct costs include petrol, oil, and lubricants (POL); maintenance by civilian contract and by RAAF personnel; replacement spares; and aircrew costs. Maintenance by RAAF personnel is called In-House Servicing (48:3).

On Costs. On costs include the administrative costs incurred in supporting a flying squadron and the cost of supplying medical, dental, office accommodation and utilities. The administrative costs are calculated as a percentage of direct operating costs. For example, 15 percent of the fuel and oil costs and 20 percent of the spares costs are added as "standard departmental on costs" (47:4).

Capital Costs. Capital costs include the amortization of the original purchase of the aircraft and the amortization cost of modifications made to maintain or improve the aircraft capability. These capital costs are calculated over the expected life of the aircraft (47:4).

Allocation of Fixed and Variable Costs

The aim of this study is to evaluate the impact of faster cruise speeds on C130E Hercules' operating costs. Fixed costs, which do not vary with changes in the number of flying hours, need to be separated from the variable costs, which change when the number of flying hours change.

Fixed Costs. Capital costs are dependent on the initial cost of the aircraft, the cost of modifications, aircraft age, and the expected service life of the aircraft (47:3). Therefore, capital costs are considered to be fixed in this study. The Director of Costing considers that On Costs are so unresponsive to changes in direct costs that they should be regarded as fixed (48). Therefore On Costs have been defined as fixed costs in this study.

Variable Costs. All Direct Costs, except crew costs, have been considered to be variable in this study. In military aviation it could be argued that the crew costs are fixed on an annual basis and do not vary with the changes in the number of flying hours. USAF aircraft operating cost calculations do not include aircrew costs because they are "relatively fixed and do not vary directly with a change in flying costs" (54:9). In this study, crew costs are considered to be fixed.

RAAF C130 Maintenance Schedule

A change in the RAAF C130 maintenance schedule during this study may have confused the distinction between fixed and variable maintenance costs. Until 1 March 1989, C130 periodical maintenance was scheduled according to a combination of elapsed days and/or flying hours (3). In the context of this study, a reduction in flying hours by flying the aircraft at a higher speed could have had an impact on the maintenance schedule and direct maintenance costs. On 1 March 1989, the RAAF introduced a revised maintenance schedule which was based only on the number of elapsed days since the last servicing (3).

The new RAAF maintenance policy appears to have the effect of making all maintenance on the C130 aircraft into a fixed cost, independent of the number of flying hours flown. Using this revised maintenance plan, an aircraft flown continuously is scheduled for maintenance at the same frequency as an aircraft which does not fly at all. The new maintenance schedule does include some variable maintenance requirements. Checks are made on some aircraft equipment based on the number of times the equipment is used or the number of flying hours. For example, the main landing gear torque strut must be inspected every 5,500 landings and the engine starter must be inspected every 4,000 flying hours (3:D1,D2). Many items on the maintenance schedule require inspection and repairs are carried out only when required. A change in flying rate may affect the physical condition of the aircraft when inspected and result in a variable maintenance requirement (33). A comparison of the old and new maintenance schedules is included at Appendix C. Evaluation of the validity of this new maintenance policy and the division of scheduled maintenance into variable and fixed costs are beyond the scope of this study.

Validity of RAAF Cost Data

The validity of the RAAF cost data for C130 Hercules aircraft is questionable. Comparison of the costs for the C130E and the C130H model Hercules in the RAAF shows that the fuel costs are the only source of variation in direct operating costs. The variation in fuel costs seems to be logical because the C130E average fuel consumption is 2,340 litres per hour and the C130H fuel consumption is 2,520 litres per hour (10). Some variation in the spares, contract servicing and in-house servicing could be anticipated because the C130E aircraft are 22 years old and the C130H aircraft are about 10 years old (11:6).

Aggregation of Data. Investigation revealed that the RAAF aggregates the spares, in-house maintenance, and contract maintenance costs for its 12 C130E and 12 C130H Hercules aircraft. In the absence of any other guidance, the Costing Section then divides these costs equally between the two types of C130 aircraft when preparing the flying hour cost rates (48). Further examination of the validity of Costing Section data was therefore undertaken as part of this study. The Costing section data for the RAAF C130E and C130H is shown in Table I.

Depot Maintenance of RAAF C130 Aircraft

Research by Foster and Hunsaker into "The Effect of

Table I

Comparison of the Operating Costs per Flying Hour for RAAF C130 Aircraft in 1988 / 1989
Source: Extracted from 47:2

Operating Costs	C130E $(AUS)	C130H $(AUS)
Direct Costs		
Petrol and Oil	648	698
Spares	643	643
Contract Servicing	494	494
In-House Servicing	639	639
Crew Costs	123	123
Total Direct Costs	$2,547	$2,597
Full Costs		
Direct Costs	2,547	2,597
On Costs	713	720
Capital Costs	272	734
Total Full Costs	$3,532	$4,051

Aircraft Age and Flying Hours on Maintenance Costs" showed that in the USAF there is a gradual trend for increasing C130 depot maintenance costs with aircraft age (11:6). This study includes C130A, C130E, and C130H aircraft. In 1983 the cost of depot maintenance for a five year old C130 was $290(US) per flying hour, at 10 years $350(US), at 15 years $405(US), and at 20 years $451(US) per flying hour (11:6). The RAAF C130E aircraft are 22 years old and the C130H aircraft are 10 years old. Therefore, according to the study of Foster and Hunsaker, there should be a difference between the depot maintenance costs for the RAAF C130E and C130H aircraft.

The planned working hours for depot servicings of RAAF C130 aircraft indicate that there is a significant difference between the maintenance costs of C130E and C130H aircraft. In 1989, 20,260 manhours were scheduled for each depot servicing of a C130E aircraft compared with 13,040 manhours for the newer C130H aircraft (20:1). Modifications of the C130E required 3,720 of the difference in manhours. An additional 3,500 manhours is attributable to the additional servicing required for C130E aircraft for corrosion and other "age-related problems" (20:2). The division of manhours planned for RAAF depot maintenance of C130 aircraft is shown on Table II.

Table II

Planned Allocation of Manhours per Aircraft for Depot Level Maintenance of RAAF C130 Aircraft in 1989
Source: Adapted from 20:3

Type of Maintenance	C130E (Manhours)	C130H (Manhours)
Depot Servicing and Rectifications	16,000	12,500
Airframe Modifications	3,000	0
Avionics Modifications	1,260	540
TOTAL	20,260	13,040

Contract Servicing of RAAF C130 Aircraft

Further confirmation that the maintenance costs of RAAF C130E and C130H aircraft were not identical was obtained from the depot servicing manpower costs performed by the RAAF civilian contractor, QANTAS, for the period from June 1987 to May 1989 (32). The range of manpower hours for C130E maintenance was 9,165.6 to 25,048 while the range for C130H aircraft was 5,687.2 to 10,526 manpower hours. This range of hours can be attributed in part to the different types of maintenance which were performed by the contractor (32:1). For example, the contractor has been responsible for repainting six C130E aircraft, which each required over 2,500 manpower hours. None of the RAAF's C130H aircraft were repainted by the civilian contractor during 1987 and 1988 (32:2).

The RAAF may request the contractor perform different types of C130E maintenance including scheduled Depot Level Maintenance (DLM), scheduled R3 servicing, aircraft painting, modifications and aircraft repairs. Therefore, it is difficult to compare the manhours worked on C130E and C130H depot servicing. The available data for some aircraft did not divide the manhours worked on different maintenance tasks. If complete data was not available, planning estimates of the manhours required to perform each task were used to estimate the manhours required for contract depot servicing on each aircraft (32:1,2). When all of the different types of maintenance are separated, the range of manpower hours for the depot servicing on the C130E Hercules is 7,178.8 to 13,722 with a standard deviation of 2,013.2. The C130H has a range of 4,803.8 to 6,724.4 manpower hours and a standard deviation of 653.9 for the same maintenance schedule. The higher variability for the C130E Hercules could be expected with the varying maintenance requirements for the older aircraft. The manpower hours used for each C130H and C130E Hercules aircraft's contract maintenance, in the period 1 July 1987 to 29 May 1989, is shown in Appendix D (32).

Actual data from 1 July 1987 to 29 May 1989 confirm the difference in RAAF C130E and C130H contract maintenance costs. The range of costs for C130E contact servicing in the period was $346,917(AUS) to $1,024,463(AUS) while the range of C130H costs was $194,283(AUS) to $433,983(AUS) (34). Costing Section does not account for the different types of servicing performed by the contractor (48). Therefore, without accounting for changes in the value of the dollar each year, the average cost of C130E contract servicing was $656,555(AUS) while the average cost of the C130H over the same period was $305,894(AUS). The cost data for contract servicing of C130 Hercules aircraft for 1987 to 1989 is included at Appendix E.

The cost data above represents the difference in manpower costs (34). Any additional costs, for spares and materials required to maintain the older C130E aircraft, should be added to the difference in manpower costs. The obvious conclusion is that the cost of C130 contract maintenance should not be apportioned equally between the C130E and C130H Hercules.

Costing Section Averaging Technique. The technique used by the Australian Costing Section to determine the contract servicing is also questionable.

> The contract servicing element is based on actual expenditure over the previous five financial years divided by the actual flying hours achieved over the same period. Previous years' expenditures are escalated to current fiscal year dollars by applying an escalation index. (47:2)

From Foster's and Hunsaker's study, the cost of depot level maintenance for C130 aircraft is expected to increase with aircraft age (11). The Costing Section's use of a simple average of the last five years contract servicing may bias the cost estimate toward the lower costs at the beginning of the five year period. The result of the costing section technique could be to underestimate the contract maintenance cost. The use of regression analysis may give more accurate estimates.

In-House Servicing

Differences appear to exist between the cost of RAAF C130E and C130H In-House servicing. In-House maintenance for RAAF C130 Hercules aircraft is the responsibility of 486 Maintenance Squadron. Personnel at 486 Squadron work on both C130E and C130H aircraft. Accurate records are not kept of the manpower hours expended on each aircraft type for day to day flight line maintenance. However, records of

486 Squadron manpower used for scheduled R3 servicings show that the average amount of overtime required to complete an R3 servicing on schedule differs for the C130E and C130H. The average C130H requires 100 to 150 manhours of overtime compared with 350 to 500 manhours for the C130E (20:2).

In an attempt to obtain some indication of the differences between the daily maintenance requirements for RAAF C130E and C130H aircraft, a survey was distributed to all Senior Non Commissioned Officers (SNCOs) at 486 Squadron who had supervisory responsibilities for C130 Hercules maintenance. Supervisors were requested to indicate their opinion of the daily C130E and C130H manpower requirements for flight line maintenance. Scope was given for the supervisors to indicate that there was no difference between the manpower hours required for maintenance of the two aircraft or to estimate a percentage difference. A copy of the survey is at Appendix F.

The total population of 19 SNCOs was surveyed over the period from 8 June 1989 to 21 July 1989. Responses were received from all 19 SNCOs.

Based on the survey results, the validity of assuming that maintenance requirements for RAAF C130E and C130H are the same is questionable. Of the 19 respondents, 17, or 89.4 percent, indicated that the RAAF C130E Hercules required more manhours of flight line maintenance than the C130H Hercules. One respondent indicated that there was no difference between the flight line manpower requirements for the two aircraft types. The other respondent indicated that the C130H flight line maintenance required more manpower than the C130E. The survey results are summarized in Appendix G. RAAF maintenance supervisors clearly do not believe that the maintenance requirements for the C130E and C130H are the same.

Spares

As part of this study, an attempt was made to define separately the spares costs for RAAF C130E and C130H aircraft. Assistance was sought from Support Group One in the RAAF's Headquarters Support Command. This group is responsible for the purchase of spares for Australian C130 aircraft. The spares purchased are not identified for specific use on either the C130E or the C130H model Hercules. In the Australian financial year ending 30 June 1989, $9.2 million(AUS) worth of spares was purchased for C130 aircraft. In the absence of any empirical data, the Officer in Charge of Support Group One suggested that a division of the spares costs equally between the C130E and C130H could be reasonable. His "educated guess" was that the "older C130E aircraft would require more spares support than the newer C130H aircraft" but he emphasized the lack of proof for such a guess (46).

An accurate estimate of the spares costs for the C130E and C130H aircraft could be made by using each aircraft's maintenance records to track each part. The removal of parts from one aircraft, for use in another aircraft, would limit the validity of this technique (40). The task of tracking the use of spares could not be completed without the expenditure of significant human and computer resources and is beyond the scope of this study. The cost and benefit of such a task needs to be fully studied before resources are committed.

RAAF Fuel Costs

The variation of fuel prices at different RAAF bases, as well as changes in world oil prices, affects the average RAAF fuel price (19). The RAAF pays for fuel, on a contract basis, at different rates at each base depending on the quantity required and the transport costs. On 1 April 1989, the contract prices for jet fuel varied from 20.92 cents per litre to 37.25 cents per litre at different RAAF bases (18:2,3). The 1988/89 fuel budget was based on an average price of 27.25 cents per litre. Average prices of jet fuel since January 1988 have varied in the range of 30.23 to 22.41 cents per litre as world oil prices change (18:4). The changes in the RAAF average jet fuel prices are shown in Appendix H (18:4). The average fuel price planned in the budget could be used in cost analysis studies; however, the variability of prices should be accounted for in sensitivity analysis (19).

Summary of RAAF C130 Cost Data Validation

Research data obtained during this study identified quantifiable differences between the depot servicing and the contract servicing performed on RAAF C130E and C130H aircraft. When surveyed, 89.4 percent of all 486 Squadron maintenance supervisors stated that flight line in-house servicing of C130E aircraft requires more resources than maintenance of C130H aircraft. Opinions of supply executives also indicates that the C130E Hercules could require more spares support than the C130H. However, neither of these opinions could be substantiated because there is no record of the division of RAAF in-house maintenance and spares data for the C130E and C130H aircraft.

The validity of the Costing Section data could be questioned because of the inaccuracies which have been demonstrated in this study. While the purpose of the Costing Section data is cost recovery, the data is the only authoritative source for aircraft operating costs. There is a temptation to use the cost data for cost analysis studies and life cycle cost studies. The RAAF needs to correct these deficiencies in the cost data before any analysis can be made for the tradeoff between increasing fuel consumption and decreasing maintenance. Valid cost data would also allow accurate consideration of the life cost of RAAF C130E and C130H aircraft. Further study of the new RAAF maintenance schedule may also be required to determine variable and fixed cost components.

The cost data for the USAF C130E Hercules will now be analyzed and divided into fixed and variable costs.

Section 3: Cost Data for USAF C130E Aircraft

The cost of operating USAF C130E aircraft is coordinated by the Cost Programs Division in the Air Force Cost Analysis Directorate. This agency updates Air Force Regulation (AFR) 173-13, which "presents program and cost factors primarily used to develop and estimate operating and support costs or resource requirements for Air Force weapon systems" (55:1). AFR 173-13 identifies "Life Cycle Factors" and "Budget Year Cost Factors" (55:1). Life Cycle Factors are the cumulative average of actual expenditures from the initial operation of a weapons system "projected out to some future budget year" which corresponds to the system "average economic life" (55:1). Budget Year Factors are used to frame the budget in a specific year and take into account anticipated changes in the logistics costs of a weapon system (55:1). The Budget Year Factors have been used in this study because the analysis is "confined to a specific budget year" (55:1).

USAF Cost Programs Division Terminology

When preparing the cost data, the USAF distinguishes between fixed, variable, and semivariable costs.

Fixed Costs. Fixed costs, such as depreciation, remain the same even when the level of activity changes (55:2). "Fixed costs such as the fixed cost of operating a support base. the fixed costs of a higher headquarters and the fixed cost of operating an air logistics center are not included" in AFR 173-13 (55:2).

Variable Costs. Variable costs are expected to change in proportion to a change in activity (55:2).

Semivariable Costs. Semivariable costs have "both fixed and variable characteristics" (55:2). Depot maintenance and support equipment are USAF examples of semivariable costs (55:2). The fixed operating cost component of a semivariable cost is identified as the "cost per primary aircraft authorized (PAA)" and the variable component is identified as a "cost per flying hour" (55:2).

USAF Fuel Cost Data

The United States Department of Defense has a complex system of setting fuel prices. The fuel pricing system and the Defense Department fuel budget system is described in Appendix I (44). The result of Department of Defense fuel price regulation is that USAF management can plan and operate its fuel budget in a stable pricing environment despite some changes in world oil prices (45).

A composite jet fuel price is used in the AFR 173-13 cost regulation. The composite price is based on the average USAF consumption of two types of jet fuel. A jet fuel designated as JP4 determines 93 percent of the composite price and 7 percent of the composite price depends on the price of a fuel designated as JP8 (55:3). The price of both grades of fuel for fiscal year 1989 is $0.61(US) per gallon and, therefore, the composite jet fuel price used in USAF fuel cost estimations is also $0.61(US) per gallon (55:Attachment 13). The composite jet fuel price is estimated several years in advance. For example, the fiscal year 1989 estimated composite jet fuel price is \$0.61(US); for fiscal year 1990 the price is \$0.55(US), and for fiscal year 1991 the price is \$0.58(US) per gallon (55:Attachment 13). The price of fuel for the next financial year is normally set by September of the preceding year so that all sections of the Department of Defense can complete their final budget plans. In the event of a major change to world prices an amended fuel price may be issued to take effect part way through a fiscal year, but this is very unusual. The last mid year change to the composite jet fuel price occurred in 1980 (45).

The composite jet fuel price is not always used throughout the USAF. Depending on the purpose of a fuel cost estimate, AFR 173-13 allows for "major command, budget appropriation consumption rates and stock fund standard prices" to be used for fuel calculations (55:3). Any doubt about the fuel cost figures used by C130E Hercules operators needed to be resolved before any potential cost savings could be proposed in this study. The Air Force Cost Center confirmed that the composite price of \$0.61(US) per gallon should be used for 1989 studies of C130E costs for the Military Airlift Command, the Air National Guard and the Air Force Reserves (7).

Analysis of USAF C130 Hercules Cost Data

The USAF, unlike the Australian Defence Department, clearly identifies fixed and variable costs (55:8). All 18 different types of C130 Hercules in service with the USAF have unique cost factors which relate to the aircraft mission and historical expenditure. Replenishment spares costs are the only costs which are identical for all of the C130 Hercules data in AFR 173-13 (55:8). The logistics cost factors used by the USAF are defined in Appendix J.

Replenishment Spares. Air Force Logistics Command prepares estimates of the replenishment spares' costs for AFR 173-13 using the Air Logistic Early Requirements Technique (ALERT). This model estimates the replenishment spares costs for a weapon system. The weapons system includes all of the different models of a particular design. For example, the C130 Hercules weapons system includes every different type of C130 aircraft. The USAF identifies a particular model of a weapons system, such as the C130E, as the "mission design series level" (1). Like the RAAF, the USAF has no capability at the present time to estimate replenishment spares' costs for a particular model aircraft such as the C130E (1). The validity of assigning replenishment costs equally to each model of C130 regardless of age or mission could be a weakness of the AFR 173-13 data and is being investigated (1).

Fuel Costs. The fuel cost data presented in AFR 173-13 are calculated using an Operations and Maintenance (O&M) average fuel consumption figure for each aircraft type (55:3). For example, the C130E fuel cost figure of $576(US) per hour is calculated by multiplying the Operations and .cp

Maintenance average fuel consumption rate of 781 gallons per hour by the composite fuel price of $0.737(US) per gallon (55:20). The fuel consumption rates vary significantly between different major users for each aircraft type. For example, the C130E aircraft in Military Airlift Command have an average fuel consumption budget of 763 gallons per hour (55:20). The fuel cost for Military Airlift Command C130E aircraft decreases from $566(US) to $562(US) per flying hour when using the 1987 composite jet fuel price of $0.737(US) per gallon. Appendix K shows the planned fuel consumption rates, in gallons per hour, for different USAF C130 Hercules users for the 1989 fiscal year (55:20).

Conversion of Pounds of Fuel to Gallons. The density of fuel varies with temperature and a standard conversion rate was required for this study. The standard for JP4 grades of jet fuel is for the weight to be in the range of 6.69 to 6.26 pounds per gallon (31). The Air Force cost center uses a single rate of 6.4 pounds per gallon for JP4 fuel in all cost calculations and this conversion rate has been used in this study (21;53).

Conversion of AFR 173-13 Data to Fiscal Year 1989. Dollar amounts for different fiscal years should normally be converted to the same fiscal year (55:3). The logistics cost factors in AFR 173-13 are for fiscal year 1989 but are shown in terms of fiscal year 1987 dollars (55:8). Conversion of 1987 dollars to 1989 dollars is achieved by using inflation factors. Inflation indices are published for each different USAF budget allocation such as procurement and operations and maintenance. Using the 1987 base year, the inflation indices for all C130 budget allocations, except fuel, are 1.071. The inflation indices for fuel is 1.241 (55:15). In calculating the 1989 dollar costs for operating C130E aircraft, the Defense Fuel Supply Center price for fuel of $0.61(US) per gallon has been used, because this price gives more accurate costs than the inflation indices (21). Appendix L shows the calculations for converting the AFR 173-13 cost factors to 1989 dollars. The total variable cost for operating a USAF C130E is $1,524(US). Subtracting the fuel cost of $476(US), the variable maintenance cost is $1,048(US). These costs may be expressed as a generalized equation for C130E operating costs as follows:

Average C130E variable direct operating costs

= Average fuel costs + Variable maintenance costs

Using AFR 173-13 cost data converted to 1989 dollars, 1989 operations and maintenance fuel consumption and a fuel price of $0.61(US) per gallon:

The average C130E variable direct operating costs

= $476(US) + $1,048(US)

= $1,524(US)

The fuel costs are only 31.2 percent of the total variable C130E operating costs. The remaining 68.8 percent of variable costs are maintenance related. Table III shows the USAF C130E operating cost for fiscal year 1989 in 1989 dollars, as calculated in Appendix L.

Table III

Logistic Cost Factors for USAF C130E Aircraft in Terms of 1989 Dollars

Variable Cost Per Flying Hour		
Cost Factor	$(US)	Percentage of Variable Cost
Consumable Supplies		
Systems	124	8.1
General	92	6.0
Depot Maintenance	476	31.3
Replenishment Spares	356	23.4
Fuel	476	31.2
Total Variable Costs	$1,524	100.0
Fixed Annual Costs Per Primary Authorized Aircraft		
	$(US)	
Depot Maintenance	202,259	
Support Equipment	28,917	
Total Fixed Costs	$231,176	

Summary of USAF C130E Cost Data

The costs for operating USAF aircraft are defined separately into fixed and variable costs for each model of the C130 Hercules. Therefore, the affect of increasing the USAF C130E cruise speed on variable costs can be studied.

A weakness in the USAF cost data could be that the replenishment spares are allocated equally to each model C130 independent of the aircraft age or mission. The problem of tracking the use of C130 Hercules spare parts in the RAAF and USAF appears to be similar.

Using 1989 cost data, the variable costs for operating a USAF C130E, have been defined as the sum of hourly fuel costs and hourly maintenance costs. The variable maintenance costs are $1,048(US) per hour. In Chapter V, the variable maintenance cost will be used in conjunction with the cost of actual fuel consumption at specific speeds to establish the effects of increasing C130E cruise speeds on operating costs.

This section has examined the validity of the available cost data and separated the C130E operating costs into fixed and variable costs. The next section examines the missions which could be flown at increased cruise speeds to reduce flight time and variable operating costs.

Section 4: Selection of Missions for Use in this Study

Not all of the RAAF and USAF C130E missions offer the potential to trade increased aircraft speed and fuel consumption for decreased flying hours and maintenance costs. For example, some training missions require pilots to practice their take off and landing skills at speeds of approximately 150 knots corresponding to aircraft speed limitations. These types of missions cannot be flown at speeds greater than 280 knots to reduce the number of flying speeds greater than 280 knots to reduce the number of flying hours (30:7-127;50).

One simple method of sorting out which missions could be flown at faster speeds is to total all of the flying hours allocated to specific roles. Each flying squadron is allocated a specific number of flying hours each year for each squadron role. The RAAF, with one C130E squadron, could identify the total flying hours for each mission category easily, but this task would be more complex for the large number of USAF C130E squadrons. An additional limitation of this method occurs if the flying hours allocated to a particular type of mission are not a good indicator of the aircraft cruising speed and the range of the task. For example, training mission hours could be used for low speed pilot take off and landing practice or for long range route training at speeds of 280 knots (27).

The RAAF and USAF mission profile analysis has been selected for use in this study. The RAAF and USAF use a computer analysis of their C130E missions to study the effect of flying hours on the structural life of the aircraft. During each flight, the flight engineer completes a mission summary form which is entered at a later date into a computer database. Each mission is then assigned to a single mission category which pertains to the effect of the mission on the aircraft structural life. This database can be used to obtain information about the percentage of flying hours and the percentage of flights in a particular type of mission (14;60). The RAAF and USAF mission profile database will now be examined and the missions which offer potential for increased cruise speeds will be identified.

RAAF C130E Mission Profile Database

In 1984 Lockheed constructed 14 average mission profiles from "approximately 10,000 flying hours" of RAAF usage data "as being representative of past, present and future C130E operations" (37:7). Data from missions since 1984 has been progressively added to the database. The database as of 21 June 1989 included 69,820 flying hours and 25,674 flights flown over a 12 year period. The definitions for each RAAF C130E mission code are listed in Appendix M (37:50).

Any recent change in the type of C130E missions could be concealed by the weight of data over the 12 year period. RAAF Headquarters Support Command was requested to extract data on the percentage of flying hours for each RAAF mission code for all available years and to extract cumulative data for the entire database. Examination of the data leads to questions about the validity of the database from 1977 to 1984. The number of flying hours in the database was much less than the number of flying hours flown. For example, for the period 1 July 1978 to 1 July 1979, only 235 flying hours were entered into the database compared with over 8,000 flying hours actually flown during that period (61:2).

The percentage of flying hours in each mission code may have annual variations in the RAAF and, therefore, a database over several years may be more accurate. For a small number of aircraft such as the RAAF's C130E fleet, some annual variation in the percentage of missions flown on a particular mission code could be expected, due to changes in tasking. From 30 June 1984 to 1 July 1988, the database included approximately 96 percent of the total flying hours flown and a cumulative database was extracted for this period. The effects of incomplete data in the period 1977 to 1984 and some changes in the missions flown by RAAF C130E aircraft could be observed in the data. For example, the percentage of flying hours flown on training mission appears as 7.7 percent in 1977 to 1984 and 10.1 percent in 1984 to 1989. This increase could reflect increased pilot training in recent years or inaccuracies in the incomplete database (60:1). RAAF Headquarters Support Command concluded that the data for the period 1 July 1984 to 30 June 1988 was the most accurate information available for RAAF C130E mission profiles (63). The mission profile summary data for the RAAF C130E is included at Table IV.

USAF C130E Mission Profile Database

Lockheed prepared the USAF C130E mission profile analysis using data collected over the period of 1980 to 1984 (5:3.2). The USAF C130E mission codes, listed in Appendix N, differ from those of the RAAF because different types of missions are performed. The accuracy of the mission code data is estimated to be within 0.5 percent of the actual distribution of USAF C130E flying hours (14).

Table IV

Categorization of RAAF C130E Flying Hours by Mission Code
Source: Compiled from 37:18-31;61:13;62:2

Mission Category	% Flying Hours 1977 - 1984	% Flying Hours 1977 to 21 June 1989	% Flying Hours 1 July 1984 to 30 June 1988
1	7.3	9.7	10.1
2	2.0	0.7	0.5
3	0.2	1.6	1.7
4	0.4	10.7	10.9
5	1.3	3.4	3.8
6	4.0	4.9	5.4
7	1.8	2.9	3.0
8	2.0	1.8	1.8
9	3.5	10.0	10.5
10	21.9	7.3	8.0
11	20.4	14.5	13.0
12	19.3	19.0	18.7
13	15.4	13.1	12.3
14	0.5	0.3	0.2

Considerable variation within mission codes is evident for the different USAF C130E users. For example, 32.75 percent of hours flown by the Reserves (AFRES) are classified as mission code 4 and 22.49 percent of hours flown by the Air National Guard (ANG) are for the same mission category. The percentage of flying hours flown for each USAF C130E mission code for the period 1980 to 1984 is shown in Table V.

Assistance from Warner Robins Air Logistics Center was sought to update the USAF C130E mission profile data. The data received for 1988 showed a change in the type of missions flown since the 1980 to 1984 summary. In 1988, 25 percent of USAF C130E flying hours were classified as low

Table V

Categorization of USAF C130E Flying Hours by Mission Code and by Major Users for the Period 1980 to 1984
Source: Reprinted from 5:Table 3-5

Mission Category	% Flying Hours USAF	% Flying Hours MAC	% Flying Hours ANG	% Flying Hours AFRES
1	15.05	14.32	17.51	18.31
2	5.62	5.6	5.76	6.14
3	9.14	9.13	10.79	7.12
4	26.05	25.81	22.49	32.75
5	24.67	22.52	33.75	20.80
6	9.67	11.27	4.92	7.06
7	0.00	0.00	0.00	0.00
8	6.36	7.70	2.42	3.90
9	3.41	3.71	2.32	3.85

level compared with less than five percent in the period from 1980 to 1984. A 14 percent change occurred in mission codes three to five (defined as shuttle and logistics missions in Appendix N) for the Air National Guard (ANG) and the Air Force Reserve (AFRES). Table VI compares the percentage of flying hours flown on shuttle and logistics missions in 1980 to 1984 with the percentage flown in 1988.

In gathering the mission profile data for this study, the objective was to ensure that the data were representative of the actual missions flown. Advice from Warner-Robins Air Logistics Center was that the mission profile data for the C130E in 1985 to 1987 was not representative of normal C130E mission profiles because some aircraft engineering restrictions had limited some types of

Table VI

Comparison of the Percentage of USAF Shuttle and Logistic Mission Flying Hours in 1980 / 1984 with the Percentage Flying Hours in 1988
Source: Compiled from 5:Table 3-5 and 14:1-15

C130E User	1980 to 1984	1988
USAF	59.86	54.76
MAC	57.96	56.36
ANG	67.03	52.06
AFRES	60.67	46.18

missions. The 1988 data included over 100,000 flying hours and was thought to be a true representation of USAF C130E missions (14). Therefore, the 1988 C130E mission profile data has been used in this study.

Selection of Mission Codes

Mission codes which offered the potential for cruising at 280 knots TAS could be utilized in this study to demonstrate the effect of cruising speed on C130E operating costs. The cruising speed used by the RAAF and USAF for each mission code was examined from the mission code descriptions. Mission codes which involved training and low level operations were considered unlikely to utilize cruise speeds of 280 knots (27;30:7-127;50). Therefore, all RAAF flying ho . identified as mission codes 1 and 14 were eliminated from consideration in the study. Similarly, USAF mission codes 1, 2, 6, 8 and 9, which include training, airdrop, low level, and combat training were considered to have little potential for cruise speeds of 280 knots TAS or higher.

From RAAF mission profile data for the selected period from 1 July 1984 to 30 June 1988 at Table IV, 80.9 percent of C130E flying hours are for mission codes 2 to 13 (62:2). From Table VI, 54.76 percent of USAF C130E flying hours are mission codes three to five which could be flown at speeds of 280 knots TAS or higher. This can be subdivided into 56.36 percent of MAC, 52.06 percent of ANG and 46.18 percent of AFRES C130E flying hours (13:1-15).

Conclusion

The civilian C130 Hercules companies which were studied emphasized the importance of variable maintenance costs and flight times rather than fuel costs. This emphasis is in contrast to the military operating polices, examined in Chapter II, which aimed to save fuel.

RAAF C130E Hercules cost data is not valid because of the aggregation of C130E and C130H costs and the subsequent division of costs equally between the two aircraft types. The quantifiable differences between the RAAF's C130E and C130H aircraft for depot servicing, contract servicing and in-house servicing have been exposed in this study. Differences between the spares and material costs for the two aircraft types could exist, but quantifying such a difference was beyond the scope and resources of this study.

The RAAF needs to improve the reliability and validity of C130 cost data and distinguish between fixed and variable costs. This information would allow cost analysis studies and life cycle cost studies to be completed accurately.

In contrast to the RAAF, the USAF cost data is defined into fixed and variable costs for each model of C130 aircraft. A weakness in this cost data exists because the replenishment spares costs are allocated equally to each model of C130 independent of aircraft age or mission. Using 1989 cost data, a generalized cost relationship for all USAF C130E aircraft is that variable costs are the sum of fuel costs and variable maintenance costs. Hourly maintenance costs are almost double the hourly fuel costs.

Approximately 54 percent of USAF C130E missions and 80 percent of RAAF C130E missions could be flown at cruising speeds greater than today's normal speed of 280 knots TAS. These percentages were derived from the C130E mission profile analysis. All missions which included low level flying, airdrop, basic training, proficiency training, and combat training were not considered because these missions could not normally be flown at 280 knots TAS or higher.

In Chapter V, the USAF cost data is used to test the hypothesis that increasing C130E cruise speeds could reduce variable operating costs. The mission profile analysis developed in this chapter is used in Chapter V to calculate potential annual savings for the USAF.

V. Testing the Study Hypothesis

Overview

The guiding hypothesis for this study is that the variable operating costs for the C130E Hercules in the RAAF and USAF can be reduced by increasing the cruise speed from the normal 280 knots true airspeed(TAS). The research in Chapter IV showed that the RAAF C130E cost data was not valid and that there was no apparent distinction between fixed and variable costs. The USAF C130E cost data had one weakness in that the replenishment spares were assigned equally to all models of C130 aircraft. However, the USAF clearly distinguishes between fixed and variable costs. Therefore, testing the study hypothesis in this chapter will be restricted to USAF C130E aircraft. The research and findings are presented in three sections.

The first section of this chapter of this chapter shows the effects on C130E variable operating costs when the cruise speed is decreased or increased from 280 knots TAS. The value of potential cost savings which could result from an increased cruise speed is then calculated using current cost data and aircraft performance data from the Flight Manual. The accuracy of the calculations and the sensitivity of savings to price changes is also examined.

The effect of different cruise speeds on operating costs is demonstrated in the second section using the MACPLAN computer flight planning system. Each demonstration flight is used to show that increasing the C130E cruise speed above 280 knots TAS results in decreased operating costs. In third section, practical limitations on increased cruise speeds are examined. The implementation of cruise speeds greater than 280 knots TAS is then considered.

Section 1: Testing the Hypothesis

The research literature reviewed in Chapter II included two different philosophies for savings on aircraft operating costs: save costs by saving fuel or save cost by saving flight time. Each of these philosophies will now be considered in the context of reducing total C130E operating costs.

Save Costs by Saving Fuel

An aircraft is flown at the maximum range speed to minimize the fuel consumption per mile of flight (52:5-7,5-8). In 1989, the maximum range speed for USAF C130E aircraft is approximately 260 knots TAS (52:5-26). Therefore the C130E could reduce fuel consumption and save fuel costs by reducing the cruise speed to approximately 260 knots TAS. Reducing the cruise speed from 280 knots TAS to 260 knots TAS leads to longer flight times for a fixed distance. Longer flying time results in an increase in maintenance costs.

The net effect of flying the C130E at the maximum range speed is that total operating costs increase. The increase in costs can be shown with a simple mathematical example.

For a C130E to fly 280 nautical miles at a TAS of 280 knots in no wind conditions, the flight time would be one hour. The cost of the same 280 nautical mile task flown at 260 knots TAS flown in conditions of no wind can be calculated as follows:

Flight time

= distance ÷ speed

= 280 nautical miles ÷ 260 knots TAS

= 1.077 hours

In 1989, the USAF C130E average variable costs for one hour were shown in Chapter IV to be \$476(US) for fuel and \$1,048(US) for maintenance. Therefore:

Maintenance costs

= number of hours X cost per hour

= 1.077 hours X \$1,048(US) per hour

= \$1,129(US)

The increased maintenance costs for flying at 260 knots TAS compared to 260 knots TAS

= \$1,129(US) - \$1,048(US)

= \$81(US).

If the cost of flying at 260 knots TAS is to be the same as flying at 280 knots TAS, the increase in maintenance cost must be equal to the decrease in fuel costs. The number of pounds of fuel which must be saved by flying at

260 knots TAS using a fuel price of $0.61(US) per gallon can be found as follows:

Number of gallons required to be saved

= $81(US) ÷ $0.61(US) per gallon

= 132.79 gallons

Number of pounds of fuel required to be saved

= 132.79 gallons X 6.4 pounds per gallon

= 849 pounds

Number of pounds required to save per hour

= 849 pounds ÷ length of the flight at 260 knots TAS

= 849 pounds ÷ 1.077 hours

= 788 pounds per hour

The C130E Performance Manual shows that the C130E Hercules is not capable of saving 788 pounds of fuel per hour when flying at 260 knots TAS (52). At aircraft weights above 90,000 pounds, the change in fuel consumption by reducing speed from 280 knots TAS to 260 knots TAS is a maximum of 600 pounds per hour. The quantity of fuel saved varies between 300 and 600 pounds with altitude and aircraft weight as shown in Appendix O, Table XIV (52:5-´ ɔ1,5-100). The data in Appendix O is for 100 percent engine performance as required by MACR 55-130 (57:11-7).

In the best case, flying at 260 knots TAS may save 600 pounds of fuel per hour. The cost of 600 pounds of fuel can be calculated as follows:

Convert 600 pounds of fuel to gallons

= 600 pounds ÷ 6.4 pounds per gallon

= 93.75 gallons

Cost of 93.75 gallons

= 93.75 gallons X $0.61(US) per gallon

= $57.18(US)

Therefore when 1989 cost factors are used, flying the C130E at 260 knots TAS saves a maximum of $57.18(US) of fuel but costs $81(US) more for maintenance compared with the same C130E flown at 280 knots TAS. The net penalty is that total operating costs increase by over $23(US) per hour. The 260 knots TAS cruise would increase operating costs by more than $23(US) per hour on most flights because the calculations above used the maximum fuel saving of 600 pounds per hour. Table XIV in Appendix O shows that fuel savings for a 260 knots TAS cruise may be as low as 300 pounds per hour. Therefore a 260 knots TAS cruise can be expected to save fuel but the dollar value of the fuel savings will be exceeded by the dollar value of the increased maintenance costs.

Save Time by Flying Faster

The effect on operating costs when the C130E is flown at speeds faster than 280 knots TAS to reduce flight times will now be examined. A TAS of 290 knots was selected for calculations because the data is in the C130 Performance Manual and can be validated using the MACPLAN computer flight planning system. A simple example will again be used to demonstrate the affects of a cruising speed of 290 knots TAS.

Consider the cost of a 280 nautical mile task flown at 290 knots TAS. The costs for the task can be calculated as follows:

Flight time

= distance ÷ speed

= 280 nautical miles ÷ 290 knots TAS

= 0.9655 hours

Maintenance costs

= number of hours X cost per hour

= 0.9655 hours X $1,048(US) per hour

= $1,011.84(US)

The saving in maintenance costs by flying at 290 knots TAS compared to 280 knots TAS is $1,048(US) minus $1,011.84(US) which equals $36.16(US).

If the cost of flying at 290 knots TAS is to be the same as flying at 280 knots TAS, the decreased maintenance cost must be equaled by an increase in fuel costs. The additional quantity of fuel which must be consumed by flying at 290 knots TAS can be found as follows:

Increased fuel consumption to break even on costs

= maintenance cost saving

= $36.16(US)

= \$36.16(US) ÷ \$0.61(US) per gallon

= 59.28 gallons

= 59.28 gallons X 6.4 pounds per gallon

= 379 pounds

Since the flight duration for 280 nautical miles at 290 knots is 0.9655 hours, the fuel savings required to break even per hour

= 379 pounds ÷ 0.9655 hours

= 392 pounds per hour

The "Range Summary Fuel Flow" charts in the C130 Performance Manual were used to estimate the increase in fuel consumption, which may be expected when the TAS is increased from 280 knots to 290 knots (52). In the worst case, the fuel consumption increases by 340 pound per hour while the minimum increase in fuel consumption was 180 pounds per hour. The data extracted from the Performance Manual is shown in Appendix O, Table XV.

Because the estimated increase in fuel consumption is less than the maximum fuel consumption to break even, the 290 knots TAS cruise will result in reduced operating costs. The reduction in costs can now be calculated for the worst case of a 340 pounds per hour increase in fuel consumption and the best case of an increase of only 180 pounds per hour.

Worst Case: 340 Pounds Per Hour Increase in Fuel Consumption.

Reduced operating cost per hour

= Maximum increase in fuel consumption to break even - 340 pounds

= 392 - 340 pounds

= 52 pounds

= 52 pounds ÷ 6.4 pounds per gallon

= 8.125 gallons

= 8.125 gallons X $0.61(US) per gallon

= $4.96(US) per hour

Therefore, in the worst case, a 290 knots TAS cruise will save $4.96(US) per flying hour.

Best Case: 180 Pounds Per Hour Increase in Fuel Consumption.

Reduced operating cost per hour

= Maximum increase in fuel consumption to break even - 180 pounds

= 392 - 180 pounds

= 212 pounds

= 212 pounds ÷ 6.4 pounds per gallon

= 33.125 gallons

= 33.125 gallons X $0.61(US) per gallon

= $20.20(US) per hour

In the best case, a 290 knots TAS cruise will save $20.20(US) per flying hour. The operating costs for a USAF C130E flying at 290 knots TAS could therefore be expected to be \$4.96(US) to \$20.20(US) per flying hour less than the same C130E being flown at 280 knots TAS.

Accuracy of Calculated Savings. The Air Force Cost Center does not place an accuracy on its aircraft cost data (7). The accuracy of the estimated savings is influenced by the interpolation of data from the C130 Performance Manual. The data in this manual is presented in graphical format. Attempts to obtain USAF performance data in a more accurate tabulated format from Military Airlift Command and Lockheed were not successful. The fuel consumption graphs can be read to an accuracy of plus or minus five pounds per hour fuel consumption per engine. The fuel consumption at one speed, 280 knots TAS, was then subtracted from another fuel consumption figure, for 290 knots TAS. Therefore, the accuracy of the difference in fuel flow could be plus or minus 10 pounds. The fuel flow in the Performance Manual is given in pounds per hour per engine. Therefore, the difference in fuel flow is multiplied by four to give the difference in fuel consumption for all four engines on the C130E. The accuracy of fuel flow is therefore multiplied by four to give an accuracy of plus or minus 40 pounds of fuel per hour.

The effect of this accuracy on the cost savings can be estimated as follows:

40 pound of fuel

$= 40 \div 6.4$ gallons

$= 6.25$ gallons

The cost of 6.25 gallons

= 6.25 gallon X \$0.61(US) per gallon

= \$3.81(US)

The interpolation of fuel consumption graphs, therefore, has an accuracy of 40 pounds per hour which is equivalent in 1989 to \$3.81(US) per hour.

The Range of Potential USAF C130E Cost Savings

An expected range of cost savings per flying hour can be estimated by applying the calculated accuracy of the graphical interpolations to the calculated range of savings. The expected range of cost savings lies between \$4.96(US) to \$20.20(US) plus or minus \$3.81(US). Therefore, in 1989, a 290 knots TAS cruise will result in savings in the range of \$1.15(US) to \$24.01(US) per C130E flying hour when compared to a 280 knots TAS cruise.

The midpoint of the range of savings when flying at 290 knots TAS is \$12.58(US) per flying hour. This midpoint could be used to represent the expected savings for different flights. Note that an average value for the hourly savings has not been defined because the C130E fuel consumption varies for different aircraft weights, altitudes, and air temperature.

Estimate of Savings For MAC

The annual savings can now be estimated when the Military Airlift Command (MAC) C130E squadrons change from a normal cruise speed of 280 knots TAS to 290 knots TAS.

Using the USAF mission profile analysis in Chapter IV, 56.36 percent of MAC C130E missions have the potential to be flown at cruise speeds of 290 knots TAS (13:1-15). In 1989, MAC is planning to fly the C130E Hercules for 111,064 flying hours; 56.36 percent of this total is 62,595 hours (7). The potential savings for MAC in 1989 can be estimated as 62,595 times $1.15(US) to $24.01(US). Therefore, MAC savings from a 290 knots TAS cruise could be in the range of $71,984(US) to $1,502,906(US) in 1989. The $12.58(US) per flying hour midpoint of the savings times 62,595 hours can be used to estimate the annual MAC savings of $787,445(US) per year. Similar savings over each year of the life of the C130E for comparable fuel and maintenance costs represent considerable savings to MAC and the USAF.

Accuracy of Estimated MAC Savings. The estimated savings for MAC should account for the accuracy of graphical data extracted from the Performance Manual and the accuracy of the USAF mission profile analysis. The estimated accuracy of the mission profile analysis is 0.5 percent (14). Applying this accuracy to the MAC flying hours gives an accuracy of 0.005 times 111,064 or 555 hours. Multiplying this accuracy by the range of $1.15(US) to $24.01(US) gives $638(US) and $13,325(US) respectively. Therefore, after correcting for interpolation of data and the accuracy of mission profile estimates, the savings to MAC when using a 290 knots TAS cruise could be expected to be in the range of $71,346(US) to $1,516,231(US) for 1989.

Summary of USAF Annual Savings

Increasing the C130E cruise speed from 280 to 290 knots TAS, could result in annual savings of $94,613(US) to $1,979,287(US) for the USAF. The midpoint of the savings range of $12.58(US) per flying hour can be used to estimate USAF savings of $1,027,017(US) per year. These savings are the total of MAC, ANG, and AFRES C130E aircraft savings calculated using 1989 cost data and 1989 planned flying hours. Table VII shows the savings for each C130E user. The savings for the ANG and AFRES are calculated in Appendix P. Savings have not been calculated for the C130E aircraft operating in the United States Forces in Europe because these C130E aircraft are scheduled to fly 1,500 hours in 1989 and the USAF does not maintain a unique mission profile analysis for these aircraft (6;14).

Table VII

Potential Annual USAF Savings for C130E Aircraft Using 290 Knots TAS Cruise Speeds in 1989

C130E User	Potential Savings $(US)	Midpoint Savings $(US)
MAC	71,346 to 1,516,231	787,445
ANG	11,926 to 221,084	114,150
AFRES	11,341 to 241,972	125,422
Total	$94,613 to 1,979,287	$1,027,017

Sensitivity of USAF Operating Costs to Fuel Prices

The sensitivity of hypothesized savings, in the C130E operating costs, to variations in fuel prices should be considered because of the historical fluctuations discussed in Chapter II and in Chapter IV. The savings in maintenance costs by flying the C130E at 290 knots TAS were shown to be $36.16(US) per hour for 1989 cost factors before any penalty for increased fuel consumption was considered.

In the worst case, the increase in fuel consumption by flying at 290 knots was shown to be 340 pounds per hour. 340 pounds is converted to 53.125 gallons by dividing by 6.4 pounds per gallon. If the $36.16(US) decrease in maintenance cost is equal to the increased cost of fuel, then 53.125 gallons would cost $36.16(US) or a fuel price of $0.6807(US) per gallon.

In the best case, the fuel consumption may only increase by 180 pounds per hour when the cruise speed is increased from 280 knots TAS to 290 knots TAS. 180 pounds of fuel is equivalent to 28.125 gallons. If 28.125 gallons cost $36.16(US), the price of fuel is $1.28(US) per gallon. Therefore, the 290 knots TAS cruise would continue to generate savings over a 280 knots TAS cruise on all flights if the fuel price was less than $0.6807(US). The 290 knots TAS cruise would continue to generate savings on some flights until the fuel price reached $1.28(US).

Effect of Maintenance Costs. On 23 June 1989, the Air Force Cost Analysis Improvement Group approved the 1990

Logistics Costs Factors for C130E Hercules (7). The variable maintenance costs for 1990, in terms of 1990 dollars, total $1,139(US) per flying hour. Using the same calculation techniques used earlier in this section, Appendix Q shows that the differential between a 280 and a 290 knots TAS cruise would be $39.30(US). From Appendix Q, the 290 knots TAS cruise would continue to give savings if the fuel consumption increased by 340 pounds per hour and the fuel price increased to $0.7398(US). When the fuel consumption increases by 180 pounds per hour, Appendix Q shows that the 290 knots TAS cruise continues to give savings over a 280 knots TAS cruise until the price of fuel reaches $1.39(US) per gallon.

Therefore, the 290 knots TAS cruise would generate cost savings on all flights in 1990 when the fuel price is less than $0.7398(US) per gallon and would continue to generate savings on some flights until the price of fuel reaches $1.39(US) per gallon.

The calculations in Section 1 used the cost data and mission profiles from Chapter IV. In the next section, the validity of the calculations is demonstrated.

Section 2: Demonstration of Hypothesis Benefits

As a further demonstration of the hypothesized benefits of this study, the Lockheed flight planning computer was utilized. This computer is used on a daily basis by RAAF and USAF C130E crews to plan their missions. The computer program, called JETPLAN, includes performance data for each model C130 and allows the aircrew to select different cruise techniques. A specialized version of JETPLAN, called MACPLAN, is used by aircrew in Military Airlift Command (MAC) and was used in this study. MACPLAN has many default computer settings which correspond to the normal operating procedures of MAC aircrew (17). The USAF MAC C130E was selected to demonstrate the benefits hypothesized in this study because MAC is the largest user of C130E Hercules aircraft (39:107).

Scope of Demonstration. There are a large number of variations in aircraft weight, payload, fuel consumption, flight distances, weather and different types of missions which no study could hope to cover entirely. Demonstration of the benefits of higher cruising speed in this study will consider the spectrum of USAF missions as being on a continuum; missions have been selected to cover the upper and lower limits of that continuum.

Types of Cruise Available. USAF C130E aircrew may select from five different types of cruise techniques when using MACPLAN. Cruise speeds of 210 knots, 260 knots, 280 knots, 290 knots or cruising at the aircraft long range cruise speed may be selected. A 210 knots cruise is flown during low level operations and was not considered in this study. A 280 knots TAS cruise is the default selection in MACPLAN and is used for most USAF missions (50).

Fuel or Time Optimization. After selecting the desired cruise technique, aircrews select whether they wish to optimize the use of fuel or optimize the flying time. When optimizing fuel, the computer program uses the selected cruise speed to arrive at the destination with the minimum fuel consumption. When time is optimized, the program uses the selected cruise speed to travel to the destination in the shortest possible time without regard for fuel consumption. Fuel optimization is the default selection in MACPLAN (17). Aircrews have found that when the option to minimize flight time is selected, the computer will often select altitudes as low as 9,000 feet despite the advantage of higher tail winds at higher altitudes (16:4). The result of selecting minimum time on MACPLAN can therefore be the saving of only one minute at the expense of an extremely high fuel consumption at 9,000 feet. Fuel optimization and time optimization are compared in the demonstration computer flight plans.

Selection of Routes. Demonstration of the benefits of the hypothesis required that actual airfields and routes be selected for input to Lockheed's flight planning computer. The criterion used was that routes should match the USAF mission profiles which had the capability of being flown at 280 knots or higher. The actual point of departure and destination for the flight was not important to the demonstration. Two of the selected flights were 1 hour and 25 minutes and 4 hours and 25 minutes in length, corresponding to the mission code boundaries in Appendix N of 1 hour 30 minutes and 4 hours 30 minutes. The departure and destination points for each demonstration, the distances between each airfield, and the approximate duration of the flight are shown in Appendix R.

The Effects of Wind and Temperature. Tail wind or headwind could distort the study of aircraft cruising speed on operating costs by affecting the flight time. The initial approach used was to avoid potential wind effects by selecting routes in equatorial regions where the winds tend to be less than 10 knots. This approach worked for short range tasks; however, it was difficult to arrange for actual weather conditions on the day a flight was planned to include light winds over distances of 2000 miles. Assistance from Lockheed resulted in the ability to program the computer for no wind and for International Standard Atmosphere (ISA) temperature conditions (17). The no wind and ISA day temperature conditions were used for all flight plans.

The Effect of Drag Index. Lockheed has developed drag indexes to indicate different variations from the basic C130E Hercules. For example, the addition of underwing fuel tanks to a C130E adds drag to the aircraft and reduces the ability of the aircraft to perform in accordance with the Performance Manual (52:1-2). The Performance Manual includes a graph which shows a correction factor to be applied to the basic C130E aircraft performance data. A positive drag index increases aircraft drag and reduces the aircraft performance when compared to the basic C130E. A drag index of plus 18 is applied to the basic C130E Hercules performance for a C130E fitted with underwing fuel tanks (52:1-2). Users of the JETPLAN computer flight planning system are unable to adjust the aircraft drag index. MACPLAN enables users to nominate a drag index in the range of minus 18 to plus 30. The default drag index in MACPLAN Version 7.12 dated 9 June 1989 is plus 18 (17). Over several years, the USAF has modified its C130E aircraft and increased the drag index to a total of plus 36 (52:1-2). Table VIII shows the differences between the basic C130E and the USAF C130E and the corresponding drag indexes.

Table VIII

USAF C130E Hercules Drag Indexes
Source: 52:1-2

Aircraft Configuration	Drag Index
External Fuel Tanks and Pylons	+ 18.0
Long HF Wire Antenna	+ 2.5
AN/APN 169A SKE Top Radar	+ 7.0
European 1 Paint	+ 3.0
Walkway Paint	+ 5.5
Total Drag Index	+ 36.0

Lockheed has received a copy of the latest USAF C130E Performance Manual but has not yet received a request for the computer flight plan performance data in MACPLAN to be amended (17). As a result of the deficiency in MACPLAN, the maximum available drag index of plus 30 was used to demonstrate the effects of varying cruise speed on operating costs.

Recording of RAAF and USAF Flight Times

When aircrews in the RAAF and USAF record the duration of a flight, they calculate the time from the start of the take off roll to the landing and then add six minutes (27;50). The addition of six minutes is a system used for most aircraft types in the military to take into account the time the engines are running when the aircraft is moving on the ground. Before recording the flight time in the maintenance records for the aircraft, the aircrews round the time to the nearest tenth of an hour. Over a large number of flights the rounding process should balance out to reflect the required flight time. In the following demonstration cases the flight times have not been rounded. This decision was made because of the small number of demonstration flights included. Rounding the data would also introduce an element of doubt as to the veracity of the calculations. Six minutes has been added to each of the flight times in the demonstration flights because of the effect on the calculated operating costs. Failure to add six minutes would have reduced the flight time and reduced the variable maintenance costs.

Methodology

After routes were selected, MACPLAN was used for each

C130E cruise speed to examine the duration of the flight and the amount of fuel used.

Effect of Aircraft Weight. The payload on the aircraft was adjusted over the maximum permissible range of aircraft operating weights to observe the effect of light and heavy aircraft on aircraft cruising technique and aircraft operating cost. For all of the selected routes, 1,000 pounds of payload was used to simulate an aircraft with approximately zero cargo. On short to medium range flights, 38,000 pounds of payload was used to bring the C130E aircraft to the limits of the aircraft manoeuvre envelope. On longer flights, the payload was added to maintain the total weight including fuel and payload, less than the maximum normal take off weight of 155,000 pounds.

MACPLAN Parameters. The computer program inputs required for the MACPLAN computer flight plans are listed at Appendix S.

Calculation of Savings

The length of each flight and the amount of fuel used was extracted from each computer flight plan printout and entered into a QUATTRO spreadsheet. The direct operating costs of each trip were then calculated and compared.

Operating Cost Equation. The variable direct operating costs for each flight were calculated using a formula as follows:

Cost

= Fuel Cost + Maintenance Cost

Fuel cost

= Fuel used in pounds X 6.4 X \$0.61(US)

where

6.4 pounds = 1 gallon
cost of fuel = \$0.61(US) per gallon

Maintenance Cost

= [(Flight Time in minutes) ÷ 60] X \$1,048(US)

where

flight time in minutes ÷ 60 = flight time in hours
cost of variable maintenance = \$1,048(US) per hour

Flight Time

= Length of flight in minutes plus 6 minutes

Savings. The savings for each different cruise technique were calculated in relation to the same flight flown over the same distance with the same payload for a 280 knots TAS fuel optimized cruise. Therefore, the savings calculated reflect the savings available in 1989 if the USAF were to change the C130E cruise policies. Negative savings imply that the 280 knots TAS cruise is less expensive than the cruise technique being compared.

Savings Per Hour. The savings per hour were calculated by dividing the savings by the flight time in hours. This flight time included the standard 6 minutes added to the time the aircraft is flying.

Summary of Flight Plan Analysis

In all of the demonstration flight plans, the operating costs for the 290 knots TAS cruise were less than the operating costs for the 280 knots TAS cruise, which is used today on most USAF C130E flights. Savings from the 290 knots TAS cruise varied from $12.85(US) to $22.86(US) per flying hour. These savings were ootained for flights varying from 324 to 2,157 nautical miles and with payloads varying from 1,000 pounds to 38,000 pounds.

The Effect of Cruise Speed on Operating Costs. The MACPLAN flight plans demonstrated the difference in operating costs for the 260, 280 and 290 knots TAS cruises, as calculated in section one of this chapter. For example, on the 324 nautical mile flight with 1,000 pounds of payload, the 260 knots TAS cruise saved 141 pounds of fuel compared to the 280 knots TAS cruise. However, the 260 knots TAS cruise was $40.17(US) per flying hour more in operating costs, because of the longer flight time. Increasing the cruise speed to 290 knots TAS resulted in savings of $16.75(US) per flying hour compared to the 280 knots TAS cruise.

Fuel or Time Optimization. The selection of time optimization in MACPLAN resulted in the shortest flight time but this did not result in the reduced operating costs. For example, on the medium range logistics flight over 1,181 nautical miles with 1,000 pounds of payload, the 280 knots TAS time optimized flight used 25,563 pounds of fuel for a flight time of 261 minutes, whereas the 280 knots TAS fuel optimized cruise used 17,412 pounds of fuel in a flight time of 265 minutes. In this example, when the effects of fuel and maintenance costs are considered, the time optimized cruise is $162.53(US) per hour more expensive than the fuel optimized cruise. For a flight of the same distance with the same payload, the 290 knots TAS fuel optimized cruise saved $22.86(US) per flying hour, in comparison to the 280 knots TAS fuel optimized cruise.

A detailed analysis of each MACPLAN flight plan is in Appendix T. The analysis of all the 290 knots TAS flights is summarized in Table IX. The flight plan labels A to G in Table IX refer to the corresponding 290 knots fuel optimization flight plans in paragraphs a to g in Appendix T. Flight plan labels H to J correspond to the long range 290 knots TAS flights in paragraph h in Appendix T.

Table IX

Summary of Variable Cost Savings Using a 290 Knots TAS Fuel Optimizing Cruise When Compared to a 280 Knots TAS Fuel Optimizing Cruise with 1989 Prices and a C130E Drag Index of 30

Flight Plan Label	Distance (nautical miles)	Time (hours and minutes)		Payload (pounds)	Savings Per Hour $(US)
A	324	1	18	1,000	16.75
B	324	1	23	38,000	17.26
C	586	2	13	1,000	19.22
D	586	2	18	38,000	22.86
E	1,181	4	16	1,000	22.86
F	1,181	4	26	38,000	12.85
G	2,157	7	41	1,000	17.74
H	2,157	7	43	10,000	16.60
I	2,157	7	47	20,000	14.29
J	2,157	7	50	25,000	13.84

Calculated Savings for MACPLAN Demonstrations. The savings calculated for the MACPLAN demonstration flights are optimistic because the computer program is limited to a drag index of 30 and USAF C130E aircraft have a drag index of 36. Using the Performance Manual, the effect of this limitation can be estimated. The drag index of 36 corresponds to a decrease in the cruise ceiling of 300 feet for a USAF C130E (52:5-36). The lower cruise ceiling equates to a 30 pounds per hour increase in fuel consumption depending on the aircraft weight and altitude (52:5 113,115). The cost of 30 pounds of jet fuel at $0.61(US) per gallon is $7.68(US). Therefore, a C130E with a drag index of 36 is $7.68(US) more expensive per flying hour than a C130E with a drag index of 30. When this correction is applied, the range of savings demonstrated for USAF C130E aircraft using the MACPLAN computer flight plan system is in the range of $5.17(US) to $15.18(US). The savings from the MACPLAN flights have been corrected for a drag index of 36 in Table X.

The corrected MACPLAN savings lie within the expected range of savings $4.96(US) to $20.20(US), calculated in section one of this chapter. The expected range of USAF savings and the accuracy range associated with interpolating the Performance Manual, were calculated in section one of this chapter, and are shown in Figure 2. Also shown are the corrected savings from Table X for each of the demonstration 290 knots TAS MACPLAN flight plans.

Table X

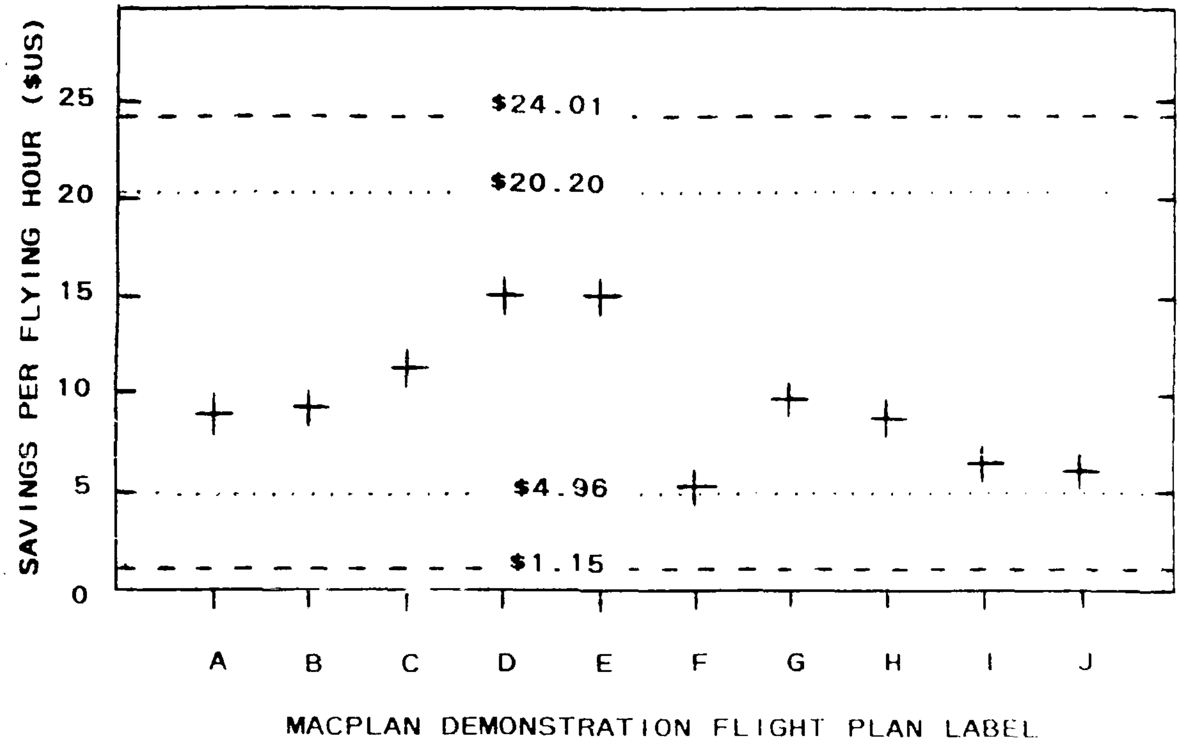
Summary of Variable Cost Savings Using 290 Knots TAS Fuel Optimizing Cruise When Compared to a 280 Knots TAS Fuel Optimizing Cruise Using 1989 Prices After Correcting for a USAF C130E Drag Index of 36

Flight Plan Label	Distance (nautical miles)	Time (hours and minutes)	Payload (pounds)	Savings Per Hour $(US)
A	324	1 18	1,000	9.07
B	324	1 23	38,000	9.58
C	586	2 13	1,000	11.54
D	586	2 18	38,000	15.18
E	1,181	4 16	1,000	15.18
F	1,181	4 26	38,000	5.17
G	2,157	7 41	1,000	10.06
H	2,157	7 43	10,000	8.92
I	2,157	7 47	20,000	6.61
J	2,157	7 50	25,000	6.16

The next section examines the practical limitations on C130E cruise speeds and the implementation of new cruise speeds.

Section 3: Implementation of Increased C130E Cruise Speeds

In Section 1, the effect of increasing the C130E cruise speed to 290 knots TAS was shown to result in annual USAF savings of between $94,613(US) and $1,979,287(US). The validity of the savings for a 290 knots TAS cruise was demonstrated in Section 2 using the MACPLAN computer flight planning system. MACPLAN does not include data for cruising C130E aircraft faster than 290 knots TAS. Therefore, the



... Indicates calculated range of savings per flying hour

– – *Indicates limit of calculation accuracy*

+ Data point from MACPLAN flight plan (Table X)

Figure 2. Predicted Range of Savings for USAF C130E Hercules Aircraft with a Drag Index of 36 Using 1989 Cost Data Showing Calculated Savings for Demonstration MACPLAN Flight Plans

effect on operating costs of cruising faster than 290 knots will be considered in this section. Practical limits to the C130E maximum speed will then be analyzed. Finally, the implementation of increased C130E cruise speeds will be considered.

Flying the C130E Faster than 290 Knots TAS

The savings when a C130E is flown faster than 290 knots

TAS can be calculated using the relationship:

Variable Cost = Fuel Cost + Maintenance Cost

Variable maintenance costs decrease as the flight time decreases. At 290 knots TAS the saving in maintenance costs in 1989 was shown to be $36 16(US). Appendix U shows that when compared with the 280 knots TAS cruise, the maintenance costs at 295 knots TAS reduce by $53.24(US) and at 300 knots TAS the costs reduce by $69.84(US).

The increase in fuel consumption at 295 or 300 knots TAS cannot be demonstrated using MACPLAN. However, it is possible to calculate the amount of fuel which would have to be consumed before the savings in maintenance costs are removed. Using $0.61(US) cents per gallon fuel costs, the 295 knots TAS cruise would break even if the fuel consumption increased by 588 pounds per hour and the 300 knots TAS cruise breaks even at an increase in fuel consumption of 786 pounds per hour. The calculations for these fuel consumptions are in Appendix V.

Further increases in C130E cruising speeds could result in a reduction in operating costs but consideration should first be given to the ability of the aircraft to achieve higher speeds.

Practical Limit on Aircraft Speed

The power available from the aircraft engines imposes a practical limit on the aircraft speed. The power available is dependent on the condition of the engine and on the air density and therefore varies with altitude and temperature.

As the aircraft weight increases the amount of power required to achieve a desired airspeed increases (58:200-205).

Assistance from Lockheed was sought for information on practical limits on C130E Hercules airspeeds. The practical speed limits for the C130E were derived using the power available and power required relationships for the C130E and a Lockheed computer program. The result was the production of a chart showing the maximum speed a C130E Hercules could achieve for varying altitudes and aircraft weights when cruising at a power setting of 910 degrees turbine inlet temperature, on an ISA day, and with the USAF drag index of 36. The chart shows that the USAF C130E, in ISA conditions, can achieve a maximum TAS of 300 knots at altitudes of 14,000 feet to 20,000 at an aircraft weight of up to 100,000 pounds. A TAS of 295 knots is achievable at aircraft weights below 130,000 pounds. The Lockheed chart is reproduced at Figure 3 (8:5).

Non USAF C130E Operators. The drag indexes may not be as high as plus 36 for non USAF users of C130E aircraft, such as the RAAF and the Canadian Forces. Aircraft with lower drag indexes may have the capability for cruising faster than 290 knots TAS (52:5-36). The Canadian Forces have unique tabulated data in their C130E Performance Manual showing fuel consumption and TAS for varying altitudes and aircraft weights. The Canadian data shows that for a C130E with a drag index of 29, 291 knots TAS can be achieved at an

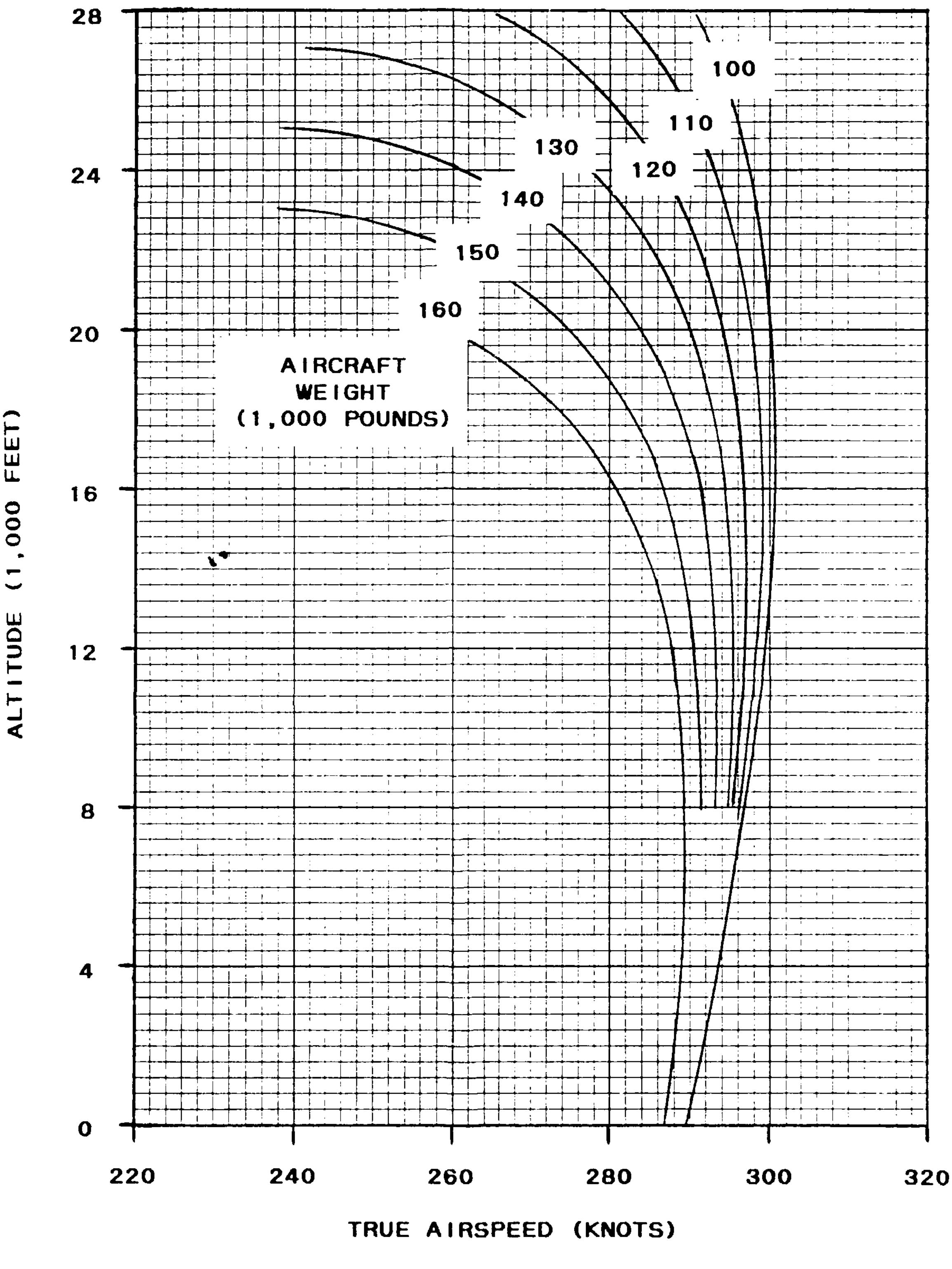


Figure 3. True Airspeed at 910 Degrees Turbine Inlet Temperature for a USAF C130E (T56-A-7 Engines, Drag Index Plus 32) in ISA Conditions
Source: Reprinted from 8:5

aircraft weight of 155,000 pounds at 14,000 feet on an ISA day using a cruise power setting of 895 degrees turbine inlet temperature. The Canadian "High Speed Cruise," which is used to minimize flight time, shows that 300 knots TAS is the maximum speed which can be maintained in the cruise on an ISA day, using 895 degrees turbine inlet temperature (36). After the RAAF determines the C130E variable operating costs, then the Canadian "High Speed Cruise" could be evaluated for its effect on operating costs.

Implementation

Engine Power Settings. At no time during this study has the suggestion been made that the existing normal engine power settings be increased to achieve a higher cruise speed. Increasing the normal cruise power could increase the cruise speed but this may be at the expense of engine life and cause the increase of maintenance costs (52:5-8). Use of increased engine power settings to increase cruise speeds is an option which would require an engineering cost and benefit analysis which is beyond the scope of this study. The calculations in this study have been made on the premise of maintaining the current normal cruise power settings at an altitude which achieves a higher cruise speed. The higher cruise speed is therefore achieved with an increase in fuel consumption but without any detriment to maintenance costs.

Implementation in the USAF. The USAF has the capability of introducing a 290 knots TAS cruise for C130E

Hercules aircraft without any delay and without any implementation costs. The necessary aircraft performance data is available within the Performance Manual (52:5-113). The MACPLAN flight planning system also has the option of a 290 knots TAS cruise (17;50). The option could remain within MACPLAN to plan a 280 knots TAS cruise if the power available were not sufficient for a 290 knot cruise.

Implementation in the RAAF. Similarly, the RAAF could also implement a 290 knots TAS cruise immediately, using the existing Performance Manual and JETPLAN data. The RAAF C130E Performance Manual does not have data for cruising at speeds greater than 290 knots TAS. Therefore, the RAAF would need to validate data, such as the Canadian C130E High Speed Cruise, before implementing cruise speeds greater than 290 knots TAS.

Saving Operating Costs at Zero Cost. While the emphasis in this study has been on saving variable C130E costs by increasing the cruising speed, an important underlying premise has been established: saving flight time saves C130E operating costs. The importance of obtaining these savings for free should not be overlooked. Aircrews have the capability to use the flight planning computers to take advantage of free reductions in flight time. Direct routes and the use of tailwinds or minimum headwinds are methods by which aircrews can reduce flight time and reduce operating costs. The computer flight plan "optimize time" option has been demonstrated to result in very high fuel usage and to increase operating costs in some cases. Some visible form of presenting the variable costs of a flight to aircrews could assist with decisions.

Visibility. A subroutine added to MACPLAN and JETPLAN could print the variable operating cost of a flight at the bottom of each flight plan. Displaying the variable cost could reinforce to aircrews their capability to operate the C130E to minimize operating costs. Aircrew could then quickly compare the costs of using a particular cruise speed for the C130E Hercules. In Appendix W is an example of a generic set of cost calculations which could be used in the MACPLAN computer flight plan program to calculate the C130E operating costs for each flight.

Conclusion

The USAF C130E Performance data was used to calculate the increase in cost when the C130E is flown at 260 knots TAS. The slower cruising speed saves a maximum of $57(US) in fuel costs but the longer flight time cause an increase of $81(US) in maintenance costs.

A decrease in maintenance costs of $31.16(US) per hour could occur when the C130E is flown at 290 knots TAS. The net savings in operating costs, after considering increased fuel consumption, has been calculated to be in the range of $1.15(US) per hour to $24.01(US) per hour. This range of values takes into account the worst case increase in fuel consumption of 600 pounds per hour, the best case of 180 pounds per hour, and the most pessimistic allowance of 40 pounds per hour for the accuracy in reading the fuel flow from the Performance Manual.

Annual savings for the USAF were shown to be in the range of $94,613(US) to $1,979,287(US). The midpoint of the savings range is $12.58(US) per flying hour, which represents an annual savings of $1,027,017(US) per year for the USAF. These annual savings were based on 1989 maintenance costs and a jet fuel price of $0.61(US) per gallon. Based on 1989 costs factors, the 290 knots TAS cruise continues to save USAF operating costs for a fuel price as low as $0.6807(US) to $1.28(US) depending on the increase in fuel consumption with aircraft weight and altitude. The 1990 cost factors would allow the fuel price to increase to $0.7398(US) per gallon before any of the 290 knots TAS cruise flights stopped reducing total operating costs.

The calculations of potential savings were validated using the MACPLAN computer flight planning system. Missions with flight times from one hour 25 minutes to seven hours 56 minutes and with aircraft payloads from 1,000 pounds to 38,000 pounds, were used to compare the variable operating costs for cruising the C130E at the different cruise speeds of 260, 280 and 280 knots TAS. In all cases the 290 knots TAS cruise had the minimum operating costs. In the MACPLAN demonstration flights, savings of $12.85(US) to $22.86(US) per hour were shown. Selection of "optimize time" in the computer flight plan program, generally resulted in higher operating costs than the 290 knots TAS fuel optimized flight plan.

The MACPLAN computer flight plan system has a maximum drag index of 30 whereas the USAF C130E has a drag index of 36. The effect of the drag index of plus 36 is to increase the operating costs by $7.68(US) per hour. Therefore, the corrected savings for the MACPLAN demonstration flights is in the range of $5.17(US) to $15.18(US) per hour. The deficiency in the MACPLAN drag index should be corrected. The current default drag index of 18 should also be altered to 30 pending corrections to the aircraft performance database.

Calculations showed that the C130E variable costs could continue to decrease as the cruising speed is increased beyond 290 knots. However, the MAC C130E is restricted to approximately 290 knots TAS except at light aircraft weights because the aircraft power and drag limits cruise speed. Aircraft with lower drag indexes such as the RAAF and Canadian C130E are capable of cruising at faster than 290 knots at most aircraft weights.

An increased normal C130E cruise speed of 290 knots could be introduced to USAF aircraft without any additional expenditure. The Performance Manual and the MACPLAN flight planning system include all of the required data. Similarly, the RAAF could also implement a 290 knots cruise overnight using the existing Performance Manual and JETPLAN data. The RAAF would need to validate data, such as the

Canadian C130E High Speed Cruise, before implementing cruise speeds greater than 290 knots TAS.

No change to current engine power settings for C130E aircraft has been considered in this study. The demonstrated savings in operating costs are achieved by cruising at an altitude appropriate for the higher cruise speed. Aircrew can use the computer flight plan to evaluate the merits of a particular route, wind conditions and cruise speed. A subroutine, like the one in Appendix W, could be added to MACPLAN and print the variable operating cost of a flight at the bottom of each flight plan. Displaying the costs could reinforce to aircrew their capability to operate the C130E to minimize operating costs.

The study has therefore shown that the C130E operating costs can be reduced by increasing cruise speeds. Chapter VI summarizes the conclusions and recommendations of this study.

VI. Conclusions and Recommendations

Overview

The objective of this study was to examine the hypothesis that operating costs for C130E Hercules aircraft in the RAAF and USAF can be reduced by increasing cruise speeds. The proposal would allow payloads to be delivered to their destination in a shorter time and at a reduced cost. This chapter draws conclusions from the research and provides recommendations for management action and further study.

Conclusions

The focus of C130E regulations in the RAAF and the USAF is on conserving fuel, without consideration of the impact that these fuel conserving polices may have on the total operating costs of the aircraft.

Since the world oil crisis in 1973, most research literature has been directed towards saving aircraft operating costs by saving fuel. The 1978 Dynamics Research Corporation report concluded that USAF C130E aircraft should be flown at 265 knots TAS to conserve fuel. This recommendation was based on the assumption that the C130E, with its turbopropeller engines, had the same operating costs as jet-engined B52 and C141 aircraft. An opposing study by the Canadian Forces in 1981 suggested that fuel costs are only one part of C130 operating costs, and fuel saving policies should be analyzed for their effect on total operating costs. The study resulted in Canadian C130 aircraft being flown at speeds between 290 and 300 knots TAS. Unfortunately the validity of the Canadian study is questionable.

In contrast to the RAAF and USAF C130E fuel saving polices, the civilian C130 Hercules companies emphasized the importance of variable maintenance costs and flight times.

The effect of cruise speeds on flight times and operating costs could be analyzed using variable costs. Therefore, fixed costs and variable costs needed to be identified and separated in this study. A change in the servicing schedule for RAAF C130E aircraft on 1 March 1989 appears to have made maintenance servicings into fixed costs. All servicings are now scheduled by the number of days since the last servicing, independent of the number of hours flown by an aircraft.

RAAF C130E Hercules cost data were analyzed and determined to be invalid. RAAF C130E and C130H costs are aggregated and divided equally between the two aircraft types. Quantifiable differences between the RAAF's C130E and C130H aircraft for depot servicing, contract servicing and in-house servicing have been exposed in this study. Depot servicing is scheduled for 20,260 manhours for the C130E compared with 13,040 hours for the C130H. The C130E is scheduled for at least 3,500 additional manhours to complete age related repairs. The average cost of contract servicing of all C130E aircraft since 1 July 1987 is \$656,555(AUS) per aircraft. This is more than double the \$305,894(AUS) average cost per aircraft for C130H contract servicing over the same period. Records at the RAAF's C130 maintenance squadron show that the C130E requires 350 to 500 hours of overtime for each R3 servicing, compared to 100 to 150 manhours for the C130H. A survey showed that 89.4 percent of all C130 maintenance supervisors believe that the RAAF C130E requires more daily flight line maintenance than the C130H. The strong conclusion is that RAAF C130E and C130H maintenance costs are not the same and should not be divided equally. The effect of increased cruise speeds on RAAF C130E operating costs was therefore impossible to determine.

Differences between the spares and material costs for the RAAF C130E and C130H could exist, but quantifying such a difference would be a major project which was beyond the scope and resources of this study. The RAAF needs to improve the reliability and validity of C130 cost data and distinguish between fixed and variable costs. This information would allow accurate completion of cost analysis studies and studies of C130E replacement costs.

In contrast to the RAAF, the USAF cost data is defined into fixed and variable costs for each model of C130 aircraft. A weakness in the USAF cost data exists because of the allocation of equal replenishment spares' costs to each model of C130, independent of aircraft age or mission.

A generalized cost relationship for all USAF C130E aircraft is that variable costs are the sum of fuel costs and variable maintenance costs. Using 1989 cost data, hourly maintenance costs of $1,048(US) are double the $476(US) average hourly fuel costs for USAF C130E aircraft. Therefore fuel conservation policies which increase flight time may increase total operating costs.

Approximately 54 percent of USAF C130E missions and 80 percent of RAAF C130E missions could be flown at cruise speeds greater than today's normal speed of 280 knots TAS. These percentages were derived from the mission profile analysis which records the number of flying hours the C130E aircraft fly in each type of mission code. All missions which included low level flying, airdrop, basic training, proficiency training, and combat training were not considered because of the likelihood that these missions could not normally be flown at speeds of 280 knots TAS or higher. The remaining missions have been used in the study.

The concept behind the study hypothesis is that faster cruise speeds can be used to reduce flight time and variable costs at the expense of increased fuel consumption. Before testing the hypothesis, the C130E Performance Manual data was used to calculate the increase in cost when the C130E is flown at the best range speed as recommended in the Dynamics Research Corporation report. The best range cruising speed saves a maximum of $57(US) in fuel costs but costs an increased $81(US) in maintenance costs because of the longer flight time.

The maintenance costs of a C130E Hercules flying at 290 knots TAS could decrease by $31.16(US) per hour. The net savings in operating costs, after considering increased fuel consumption, has been calculated to be in the range of $1.15(US) per hour to $24.01(US) per hour. This range of values takes into account the worst case increase in fuel consumption of 600 pounds per hour, the best case of 180 pounds per hour, and the most pessimistic allowance of 40 pounds per hour for the accuracy in calculating the four-engine fuel consumption from the Performance Manual. The cost savings apply to calculations over all aircraft weights.

When 1989 prices and flying hours allocations are used, a 290 knots TAS cruise speed was calculated to save the USAF $94,613(US) to $1,979,287(US) per year compared using the current 280 knots TAS cruise. These figures are the sum of MAC savings of $71,346(US) to $1,516,231(US); ANG savings of $11,926(US) to $221,084(US); and AFRES savings of $11,341(US) to $241,972(US). The midpoint of the savings range is $12.58(US) per flying hour, which represents USAF savings of $1,027,017 per year. The 290 knots TAS cruise would continue to save USAF operating costs if the fuel price increased in the range of $0.68(US) to $1.28(US), depending on the change in fuel consumption with different aircraft weights and altitudes. When 1990 Logistics Cost

Factors are used, the price of fuel could increase to $0.7398(US) per gallon before any of the 290 knots TAS flights would fail to generate a reduction in C130E operating costs. Some 290 knots TAS flights would continue to produce savings for 1990 costs until the price of fuel reached $1.39(US) per gallon.

The calculations of potential savings were validated using the MACPLAN computer flight planning system. Missions with flight times from one hour 25 minutes to seven hours 56 minutes, and with aircraft payloads from 1,000 pounds to 38,000 pounds, were used to compare the variable operating costs for cruising the C130E at the different cruise speeds at 260, 280 and 280 knots TAS. In all cases the 290 knots TAS cruise had the minimum operating costs. In the MACPLAN demonstration flights, savings of $12.85(US) to $22.86(US) per hour were shown. Selection of "optimize time" in the computer flight plan program generally resulted in higher operating costs than the 290 knots TAS fuel optimized flight plan.

The MACPLAN computer flight plan system has a maximum drag index of 30 whereas the MAC C130E has a drag index of 36. A correction of $7.68(US) per hour was calculated to compensate for the difference in drag index. Using this correction, the MACPLAN demonstration flight plans produce savings of $5.17(US) to $15.18(US) per hour. The deficiency in the drag index section of the MACPLAN program should be corrected. The current default drag index of 18 should also be altered to 30 pending corrections to the aircraft performance database.

Calculations showed that the C130E variable costs could continue to decrease as the cruising speed is increased beyond 290 knots. However, the USAF C130E is restricted to approximately 290 knots TAS, except at light aircraft weights, because of the practical limitations imposed by the aircraft power and drag. Aircraft with lower drag indexes, such as the RAAF and Canadian C130E, are capable of cruising at speeds of up to 300 knots, at most aircraft weights.

An increased normal C130E cruise speed of 290 knots could be introduced immediately to USAF aircraft without any additional expenditure. The Performance Manual and the MACPLAN flight planning system include all of the required data. Similarly, the RAAF could also implement a 290 knots cruise immediately, using the existing Performance Manual and JETPLAN data. The RAAF would need to validate data, such as the Canadian C130E High Speed Cruise, before implementing cruise speeds greater than 290 knots TAS.

No change to current engine power settings for C130E aircraft has been considered in this study. The demonstrated savings in operating costs are achieved by cruising at an altitude appropriate for the higher cruise speed. Aircrew can use the computer flight plan to reduce flight time and operating costs, by examining the effects of a particular route, wind conditions and cruise speed. A subroutine added to the MACPLAN could print at the bottom of each flight plan, the variable operating cost of a flight. Displaying the costs could reinforce to aircrew their capability to operate the C130E to minimize operating costs.

Recommendations

This study recommends that the USAF reduce C130E Hercules operating costs by implementing a 290 knots TAS cruise. The USAF could immediately save between $94,613(US) and $1,979,287(US) each year and there are no costs for implementation. All of the data required for a 290 knots TAS cruise is already in the Flight Manual and the computer flight planning system.

The MACPLAN computer flight planning system should be reprogrammed to accurately portray the flight of a USAF C130E. The current program is limited to a drag index of 30 while the standard USAF C130E, with external tanks, SKE radar and European paint, has a drag index of 36. The default drag index in MACPLAN should be increased immediately to 30 until the reprogramming is complete.

Aircrews should be given sufficient information about the cost of a flight so that they may optimize operating costs when mission requirements allow. The flight planning computer should include a program which calculates the cost of a flight and displays the cost at the end of the flight plan.

The operating costs of RAAF C130E and C130H aircraft should be more accurately determined. This study is unable to recommend immediate implementation of cruise speeds greater than 280 knots for the RAAF C130E aircraft because of inaccurate operating cost data. Accurate cost data could be used in future studies such as the C130E aircraft life cycle cost and the comparison of the C130E costs with replacement aircraft costs.

Further Research

The hypothesis used in this study could be applied to other aircraft which have relatively high variable maintenance costs compared to their fuel costs. Each aircraft should be studied on an individual basis because of the different tradeoffs between fuel consumption and speed. As a starting point, the techniques in this study could be applied to turbopropeller aircraft such as the RAAF and USAF C130H aircraft and P3 Orion aircraft flown by the RAAF and United States Navy.

The effect of aircraft age on variable operating costs could also be studied, to determine if the cruise speeds of some aircraft should be increased with age. A study of paint technology may lead to the use of a paint which meets the operational camouflage requirements of the European paint used by the USAF, but reduces the drag index to allow increased cruising speeds, fuel economy and decreased operating costs.

Appendix A: Terminology

This appendix defines some of the terms and acronyms used within this study.

AFR	[United States] Air Force Regulation.
AFRES	[United States] Air Force Reserve.
ALERT	Air Logistics Early Requirements Technique.
ANG	[United States] Air National Guard.
AUS	Australian.
CAN	Canadian.
CRUISE	The phase of flight when the aircraft has finished climbing and is maintaining a constant altitude.
DLM	Depot Level Maintenance.
DTIC	Defense Technical Information Center.
HRS	Hours.
ICAO	International Civil Aviation Organization.
IROS	Increase[d] Reliability Operational System.
ISA	International Standard Atmosphere.
JETPLAN	A computer flight planning system used by the RAAF and Canadian C130E squadrons.
LBS	Pounds.
MAC	Military Airlift Command.
MACPLAN	A computer flight planning system used by USAF C130E squadrons.
MACR	Military Airlift Command Regulation.
MINS	Minutes.

MTFA	Minimum Time for Fuel Available. A cruise technique used by the Canadian Forces.
OPEC	Organization of Petroleum Exporting Countries.
R1, R2, R3, R4	Scheduled servicings in the RAAF.
RANGE	The distance which an aircraft is able to fly with a defined amount of fuel. Maximizing the range requires that the fuel used per unit of distance be a minimum. For aerodynamic reasons, which are beyond the scope of this paper, the maximum range for an aircraft at a specified weight will occur at only one airspeed, called the maximum range speed as shown on Figure 1.
SNCO	Senior Non Commissioned Officer.
TAS	True Air Speed.
TRUE AIR SPEED	The speed at which an aircraft will travel in no wind. This speed is measured in knots. One knot is a speed of one nautical mile per hour. 100 knots is equivalent to 125 miles per hour.
TURBINE INLET TEMPERATURE	A measure of the power being generated by an engine. Many C130 operators use the throttles to set a specific turbine inlet temperature during the climb and the cruise.
US	United States.

Appendix B: Australian Costing Section Terminology and Methodology for Determining Flying Hour Rates

The following information is quoted from personal correspondence to the author by David Spouse, David, Director of Costing Department of Defence, Canberra (47).

Full Cost

Full cost(s) comprise direct costs plus on costs [and] capital costs.

Direct Costs

[Direct costs include] Petrol, Oils, and Lubricants (POL); replacement spares; contract servicing; In-House Servicing and Crew Costs.

a. Petrol, Oils and Lubricants. The average price per liter is multiplied by [the number of] liters consumed per hour for each aircraft type.

b. Spares. RAAF spares rates are based on the previous five years obligations for Air Stores and Electrical,divided by the actual flying hours for the same period. Previous years obligations and expenditures are escalated to current fiscal year dollars by applying an escalation indice.

c. Contract Servicing. The contract servicing element is based on actual expenditure over the previous five financial years divided by actual flying hours achieved over the same period. Previous years expenditures are escalated to current fiscal year dollars by applying an escalation indice.

d. In-House Servicing. An average cost per manhour is calculated for each squadron with a servicing capability. The total cost is divided by the number of personnel in the squadron to obtain the average manhour cost per squadron. This [average cost] is then multiplied by the maintenance manhours per aircraft type to achieve the total cost of maintenance manhours expended per aircraft per squadron. If more than one squadron performs maintenance for a single aircraft type, the hours are added to calculate an overall maintenance cost for that aircraft type. The final total is divided by the actual hours flown for the aircraft type in the previous financial year.

e. Crew Costs. The cost per hour of the average crew complement is determined by multiplying the number of personnel for each nominated position by rank at the direct cost level per aircraft type.

On Costs

Standard Departmental On Costs are applied to the [direct cost] elements at the following percentages:

Petrol, Oils and Lubricants	15 percent
Spares	20 percent
Contract Servicing	5 percent

[The On Costs for] squadron servicing, depot servicing and crew costs [are calculated using] the general service rate plus the base support rate.

a. General Service Rate. The general service rate represents the cost per employee to the Department of Defence for providing services of a general nature such as medical and dental services, office accommodation and utilities. [Cost] components are extracted from [the budget] Appropriations Bill Number One.

b. Base Support Rate. The base support rate represents the administrative support costs per employee for an operational area to function effectively. The civilian base support rate is advise by the Public Service Board.... The military Base Support Rate is derived from administrative support costs at nine RAAF Base Squadrons.

Capital Costs

[Capital costs include] the amortization of the original purchase of the aircraft and the amortization cost of modifications [made to maintain or improve the aircraft capability]. The two components of capital cost are then added to obtain the capital cost element.

a. Amortization, Interest on Capital. [The amortization interest on capital] is calculated by taking the capital cost of the aircraft type and multiplying the cost by the capital recovery factor, according to the aircraft's life of type. This cost is then divided by the actual flying hours for the previous financial year to give a cost per hour.

b. Modifications. Expenditure [on modifications] for the financial year is multiplied by a factor according to the remaining life of the aircraft and then added [to earlier amortization calculations on the aircraft capital cost]. This progressive cost is divided by the actual flying hour in the previous financial year to give a cost per hour.

Appendix C: RAAF C130 Maintenance Schedules

This appendix shows the changes in the RAAF C130 servicing schedules effective on 1 March 1989. The information is reprinted from Headquarters Support Command letter entitled "C130E and H Aircraft - Introduction of Revised Maintenance Requirements" (3:2).

Type of Servicing	Schedule Before 1 March 1989	Schedule After 1 March 1989
R1	30 days	45 days
R2	320 flying hours	176 days
R3	1200 flying hours or 100 weeks	76 weeks
R4	640 flying hours	Incorporated into R2 and R3
DLM	3400 flying hours or 140 weeks	158 weeks

Appendix D: Manpower Hours Worked on Contract Servicing of RAAF C130 Aircraft During the Period 1987 to 1989

This appendix shows the manpower hours worked by civilian contract maintenance on RAAF C130 aircraft. The data was compiled from personal correspondence to the author from SQNLDR N. Olliff, RAAF Resident Engineer QANTAS (32).

All data was rounded to the nearest manpower hour. The mean and standard deviation were calculated using the spreadsheet QUATTRO. Some of the types of maintenance which were performed by the contractor were not itemized. An asterisk, *, indicates that planning estimates of the required manpower hours, have been included in tne data. A # indicates that the data includes the manhours for the aircraft repaint within the modification subtotal. The C130E aircraft are listed separately from the C130H aircraft and are then listed in the chronological order in which they were serviced. There is no significance to the number of C130E and C130H aircraft which were serviced during the period. Other aircraft had similar servicings performed by the RAAF's NO 2 Aircraft Depot.

Manpower Hours Worked on Contract Maintenance of RAAF C130E
During the Period 1 July 1987 to 30 April 1989

Aircraft Tail Number	Manpower Hours For Each Type of Maintenance					
	S3	R3	Paint	Modify	Depot	Total
160	300*	0	0	74	8,791	9,165
168	0	0	0	3,486#	11,611	15,097
159	0	4,500*	2,500*	251	7,178	14,429
172	300*	0	0	3,492#	12,157	15,949
167	300*	0	2,732	113	8,140	11,285
177	300*	4,500*	3,144	97	10,338	18,379
172	300*	4,500*	3,366	1,345	9,317	18,828
180	300*	4,500*	3,174	670	11,698	20,342
189	300*	4,500*	3,512	3,014	13,722	25,048
				Mean	10,328	16,502
			Standard Deviation		2,013	4,525

Manpower Hours Worked on Contract Maintenance of RAAF C130H
During the Period 1 July 1987 to 30 April 1989

Aircraft Tail Number	Manpower Hours For Each Type of Maintenance					
	S3	R3	Paint	Modify	Depot	Total
006	300*	0	0	0	5,387	5,687
004	0*	0	0	0	5,133	5,133
009	300*	0	0	30	6,724	7,054
010	300*	4,500*	0	99	4,803	9,702
011	300*	4,500*	0	118	5,608	10,526
				Mean	5,331	7,620
			Standard Deviation		653	2,145

* indicates an estimate base on planned manpower hours.
\# indicates the modifications manpower hour include time spent painting the aircraft.

Appendix E: Cost of Civilian Contract Servicings Performed on RAAF C130 Hercules Aircraft from 1987 to 1989

This appendix shows the cost of civilian contract servicing for the RAAF C130 aircraft in the period 1987 to 29 May 1989 corresponding to the manpower hours listed in Appendix D. The cost of each service does not include any parts or materials. The cost of each service varies with both the number of manpower hours and the cost of each manpower hour. The cost for a manpower hour on 1 July 1987 was $37.85(AUS). This cost increased to $40.90(AUS) on 1 July 1988 and then to $45.60(AUS) on 1 July 1989. Work performed overlaps the change in rates. The costs listed are in terms of the dollar costs in the year they were paid.

The data was obtained from the RAAF Resident Engineer SQNLDR N. Olliff (34).

Aircraft Tail Number	Cost of Contract Servicing ($AUS)
C130E	
160	346,917
168	571,455
159	547,248
172	603,695
167	461,555
177	751,707
172	770,062
180	831,984
189	1,024,463
C130H	
006	215,260
004	194,283
009	288,506
010	397,441
011	433,983

Appendix F: Survey Of RAAF C130 Hercules Flight Line Maintenance Supervisors

This appendix includes a statement as to the purpose of the survey and the survey instrument which were both sent to 486 Maintenance Squadron C130 Hercules Maintenance Supervisors.

Purpose of Survey

This survey is being distributed to all Senior Non Commissioned Officers at 486 Squadron who have supervisory responsibilities for C130 Hercules maintenance. Each supervisor is requested to complete the survey based on personal experience and opinion. The information gathered in the survey is being used in a study of the operating costs for the C130E Hercules compared with the operating costs of the C130H Hercules. You do not need to indicate your name on the survey. The survey will take less than five minutes to complete. Thank you for your cooperation.

Survey Of RAAF C130 Hercules Flight Line Maintenance Supervisors

The following questions should be answered on the basis of your personal experience and opinions about flight line maintenance of C130H and C130E aircraft.

1. Please indicate your mustering

   airframe ......
   electrical ......
   engine ......
   instrument ......
   radio ......
   officer ......

2. Optional Question. How long have you been involved in supervising flight line maintenance?

   ....years ....months

3. Apart from scheduled servings such as R1, R2, R3, and DLM, do you believe that there is any difference in the number of manhours required to keep C130E aircraft serviceable compared with C130H aircraft?

   No, there is no difference ....

   Yes, there is a difference in my mustering ....

   Yes, but this difference is not in my mustering ....

If you answered NO, go to question 5.

If you answered YES, continue with question 4.

4. Which model C130 aircraft requires the most manhours of flight line maintenance?

   C130E ....

   C130H ....

5. What is your estimate of the percentage difference in manhours worked on flight line maintenance for the C130E and C130H?

Indicate which aircraft type corresponds to your opinion: for example 55...... 45......

50......	50......
55......	45......
60......	40......
65......	35......
70......	30......
75......	25......
80......	20......

6. Do you have any other comments about the differences in maintenance of C130E and C130H aircraft? (Use the back of this sheet if necessary).

Appendix G: Results of Survey About RAAF C130 Flight Line Maintenance

This appendix shows the results of a survey of the flight line maintenance supervisors responsible for C130 maintenance at 486 Squadron RAAF Base Richmond. The population of 19 SNCOs was surveyed over the period from 8 June 1989 to 21 July 1989. Responses were received from all 19 SNCOS.

Survey Question

Apart from scheduled servings such as R1, R2, R3, and DLM, do you believe that there is any difference in the number of manhours required to keep C130E aircraft serviceable compared with C130H aircraft?

No, there is no difference ....

Yes, there is a difference ....

Results

	Number	Percentage
No, there is no difference	1	5.3
Yes, there is a difference	18	94.7
Total	19	100.0

Survey Question

Which model C130 aircraft requires the most manhours of flight line maintenance?

C130E ....

C130H ....

Results

	Number	Percentage
C130E more than C130H	17	89.4
C130H more than C130E	1	5.3
C130E and C130H the same	1	5.3
Total	19	100.0

Survey Question

What is your estimate of the percentage difference in manhours worked on flight line maintenance for the C130E and C130H?

Indicate which aircraft type corresponds to your opinion: for example 55...... 45......

50...... 50......
55...... 45......
60...... 40......
65...... 35......
70...... 30......
75...... 25......
80...... 20......

Results

	Number	Percentage
C130E 60 percent C130H 40 percent	11	57.3
C130E 55 percent C130H 45 percent	6	31.5
C130E 50 percent C130H 50 percent	1	5.3
C130E 35 percent C130H 65 percent	1	5.3
Total	19	100.0

Analysis of Responses by SNCO Trade

The responses of the SNCOs have been collated in their trade groups. The respondents who replied that the

Maintenance manhours for the C130E and C130H are the same are indicated by C130E = C130H. Respondents who replied that the C130H required more manhours than the C130E are indicated by C130H > C130E. Those who replied that the C130E required more manhours are indicated by C130E > C130H.

SNCO Trade	Supervisor Response		
	C130E = C130H	C130H > C130E	C130E > C130H
Airframe	-	-	5
Radio	-	-	2
Instrument	-	-	2
Electrical	-	-	2
Engine	1	1	6
Total	1	1	17

Appendix H: Changes in the Average RAAF Fuel Prices for the Period January 1988 to April 1989

This appendix shows the average fuel price per litre for all RAAF bases for the period 1 January 1988 to 30 April 1989. The data was obtained from personal correspondence to the author from WGCDR P.R. Johnson, RAAF (18).

Year	Month	Cost per Litre ($AUS)
1988	January	0.2919
	February	0.3023
	March	0.3023
	April	0.3023
	May	0.3023
	June	0.3023
	July	0.2598
	August	0.2524
	September	0.2486
	October	0.2241
	November	0.2241
	December	0.2241
1989	January	0.2241
	February	0.2323
	March	0.2354
	April	0.2672

Appendix I: United States Department of Defense Fuel Prices

This appendix begins by defining some of the terminology used within the United States Department of Defense in relation to fuel costs. Then the method of establishing fuel prices within the department is explained. The information is compiled from personal correspondence to the author from L. Smith, Lead Budget Analyst Air Force Stock Fund (44).

Terminology

RAC Cost. "RAC cost" is the "price of the crude" oil "product free on board" at the refinery.

Product Cost. "The product cost is" the "worldwide average cost to the Defense Fuels Supply Center for refined" oil product.

Price Mechanism

The Office of Management and Budget (OMB) estimates the RAC price for each year. The Office of the Secretary of Defense (OSD) quantifies the annual change in the OMB RAC cost. OSD then adds the estimated transportation and storage costs for a particular budget year. The total of these calculations becomes the Department of Defense "composite cost per barrel". The Defense Fuels Supply Center uses the composite price to determine the sales price of each grade of fuel to all Department of Defense agencies. The sales prices are guaranteed by the Defense Fuels Supply Center at least one year in advance under the Department of

Defense Price Stabilization Policy. Therefore each agency has a predictable budget.

Difference between Sales Price and Actual Price

The guaranteed stabilization sales price may be too high or too low due to actual procurement costs varying from the costs anticipated in the budget. When the guaranteed price is higher than the actual procurement price, the Defense Fuels Supply center generates excess cash which is usually transferred or refunded to customers. When the guaranteed price is lower than the actual procurement price, the Defense Fuels Supply Center uses the available stock fund cash. When the cash balance in the stock fund is too low, the Price Stabilization Policy may be broken and the price charged to defense agencies may be increased. Additional budget allocations may also be sought. In 1989 the Defense Fuels Supply Center set a stabilized sales price of $21.65(US) per barrel which was $4.81(US) more than the procurement price. The anticipated profits were transferred back to customers.

The stabilized sales price for fiscal year 1990 is $23.56(US) but this is will be reviewed in September 1989 due to the changes in oil prices following the oil spill in Alaska early in 1989.

Appendix J: USAF Logistic Cost Factors

The USAF Logistic Cost Factor definitions are reprinted from the United States Air Force "Cost and Planning Factors" in AFR 173-13 (55:3,4).

Contract Maintenance

Contract maintenance is performed under contract by private; commercial organizations using contractor personnel and facilities or government-furnished materials and facilities. Contract costs include payments to contractors and the dollar value of government furnished material provided to the contractor.

Depot Maintenance Costs

Aircraft depot maintenance costs include all organic and contract elements incurred by the Depot Maintenance Service; Air Force Industrial Fund to inspect, repair, overhaul or perform other maintenance not performed at base level. Depot costs ...[include] class IV and class V modifications.... Modification costs only include labor installation only; hardware costs for modification kits are estimated separately.

a. Class IV Modifications. Class IV Modifications consist of retrofit changes required to ensure safety of personnel, systems, or equipment.

b. Class V Modifications. Class V modifications provide new or improved operational capability.

Flying Hour Consumable Supplies

[The flying hour consumable supplies are the] expendable supplies, associated directly with the flying mission (nuts, bolts and small tools).

Fuel Costs

[The fuel cost is based on] the Air Force composite jet fuel price of $0.61(US) per gallon. The composite [fuel] price was derived from ... the consumption of 93 percent JP4 and 7 percent JP8.

Organic Depot Maintenance

Organic [maintenance] refers to maintenance performed by the Air Force using government owned or controlled facilities, equipment, and military or civilian government personnel. Organic costs include civilian labor, military labor, material expense and overhead expense.

Replenishment Spares

Replenishment spares are high cost reparable items... which are repaired when damaged, as long as the estimated cost of repair is 65 percent or less than the acquisition cost.... The replenishment spares factors only includes the estimated cost to procure spares and does not include the cost of repairing the spares. The cost of repairing the spares is included in the depot maintenance factors or the base-level maintenance costs.

Support Equipment

[The Support Cost] is the yearly cost to replace organizational and intermediate base level support equipment used in direct support of aircraft requirements for out of production aircraft as well as common support for new aircraft entering the inventory.

Appendix K: USAF Appropriation or Major Command Fuel Consumption Factors in US gallons per Flying Hour for Fiscal Year 1989

The information in this appendix is reprinted from United States Air Force "USAF Cost and Planning Factors" AFR 173-13 Table 2-9 (55:20).

USAF Appropriation or Major Command	C130E	C130H
Operations and Maintenance	781	786
Air Force Reserve	712	812
Air National Guard	768	837
Air Force Europe	837	-
Military Airlift Command	763	824

Appendix L: Conversion of AFR 173-13 Logistics Data from Fiscal Year 1987 Dollars to Fiscal Year 1989 Dollars

This appendix shows the conversion of the logistic cost data from fiscal year 1987 dollars to fiscal year 1989 dollars. C130E and C130H data are included in this appendix as a source of comparison for the difference between the operating costs for these two aircraft in the USAF. The cost data from AFR 173-13 dated 9 March 1988 is shown on Table XI.

Conversion of 1987 dollars to 1989 dollars is achieved by using inflation factors. Table 2-5 of AFR 173-13 lists USAF RAW Inflation Indices for base years from 1983 to 1990. An inflation indices is published for each different USAF budget allocation such as procurement and operations and maintenance. The 1987 inflation indices required to convert Table XI data to 1989 dollars are shown on Table XII.

The logistics cost factors in Table XI are converted from 1987 dollars to 1989 dollars by multiplying them by the inflation indices in Table XII. In calculating the 1989 dollar costs for operating C130E aircraft, the Defense Fuel Supply Center price for fuel of $0.61(US) has been used because this price gives more accurate costs than the inflation indices (21) The results of these calculation are shown on Table XIII.

Table XI

Logistic Cost Factors for USAF C130E and C130H Aircraft for Fiscal Year 1989 Budget Expressed in Terms of 1987 Dollars
Source: 55:8

Variable Cost Per Flying Hour		
Cost Factor	C130E	C130H
	$(US)	$(US)
Consumable Supplies		
Systems	116	56
General	86	145
Depot Maintenance	444	310
Replenishment Spares	332	332
Fuel	576	579
Total Variable Costs	$1,554	$1,422
Fixed Annual Costs Per Primary Authorized Aircraft		
Cost Factor	C130E	C130H
	$(US)	$(US)
Depot Maintenance		
Support Equipment	195,387	93,000
Total Fixed Costs	$220,587	$120,000

Table XII

Inflation Indices to Convert Logistic Cost Factors from Fiscal Year 1987 Dollars to Fiscal Year 1989 Dollars
Source: 55:92

Logistics Factors	Applicable Inflation Indices Title	Indices
Consumable Supplies	Non Aircraft Procurement	1.071
Depot Maintenance	Operations and Management For non Petrol and Oil	1.071
Replenishment Spares	Aircraft Procurement	1.071
Fuel	Fuel	1.241
Support Equipment	Aircraft Procurement	1.071

Table XIII

Logistic Cost Factors for USAF C130E and C130H Hercules Aircraft in Terms of 1987 and 1989 US Dollars

Variable Cost Per Flying Hour				
Cost Factor	1987 Dollars		1989 Dollars	
	C130E	C130H	C130E	C130H
Consumable Supplies				
Systems	116	56	124	60
General	56	145	60	155
Depot Maintenance	444	310	476	332
Replenishment Spares	332	332	356	356
Fuel	576	579	476	479
Total Variable Costs	$1,554	$1,422	$1,492	$1,382

Fixed Annual Costs Per Primary Authorized Aircraft				
Cost Factor	1987 Dollars		1989 Dollars	
	C130E	C130H	C130E	C130H
Depot Maintenance	195,387	93,000	202,259	99,603
Support Equipment	27,000	27,000	28,917	28,917
Total Fixed Costs	$220,587	$120,000	$231,176	$128,520

Appendix M: RAAF C130E Hercules Mission Codes

The following information was compiled from the RAAF "C130 Hercules Structural Integrity Position Statement Issue 5" (37).

Mission Code	Mission Type	Description
1	Basic Training	Less than 4.5 hours and includes training
2	Shuttle	Less than 1.5 hours and Take off fuel greater than 32,000 pounds.
3	Shuttle	Less than 1.5 hours; Fuel greater than 27,000 but less than 32,000 pounds; and Cargo greater than 10,000 pounds
4	Shuttle	Less than 1.5 hours; Fuel greater than 27,000 but less than 32,000 pounds; Cargo less than or equal to 10,000 pounds.
5	Shuttle	Less than 1.5 hours and Fuel greater than 20,000 but less than or equal to 27,000 pounds.
6	Shuttle	Less than 1.5 hours and fuel less than 20,000 pounds.
7	Short Range Logistics	Less than 4.5 hours but greater than or equal to 1.5 hours; Fuel greater than 34,000; and Cargo less than or equal to 10,000 pounds.

Mission Code	Mission Type	Description
8	Short Range Logistics	Less than 4.5 hours but greater than or equal to 1.5 hours; Fuel greater than 34,000; and Cargo greater than 10,000 but less than or equal to 20,000 pounds.
9	Short Range Logistics	Less than 4.5 hours but greater than or equal to 1.5 hours; Fuel greater than 34,000; and Cargo less than or equal to 10,000 pounds.
10	Short Range Logistics	Less than 4.5 hours but greater than or equal to 1.5 hours and Fuel less than or equal to 34,000 pounds.
11	Long Range Logistics	Greater than or equal to 4.5 hours and Cargo less than or equal to 10,000 pounds.
12	Long Range Logistics	Greater than or equal to 4.5 hours and Cargo greater than 10,000 but less or equal to 20,000 pounds.
13	Long Range Logistics	Greater than or equal to 4.5 hours and Cargo greater than 20,000 pounds
14	Low Level	Altitude less than or equal to 2,000 feet above ground level for more than 30 minutes and Airspeed greater than 190 knots.

Appendix N: USAF C130E Hercules Mission Codes

The following data is reprinted from a report by O.G. Crooks et al. entitled "FY85 C130 Service Life Analysis" (5:3-5).

Mission Code	Mission Type	Description
1	Proficiency Training	Sortie that contains both touch-and-go and stop-and-go type intermediate landings.
2	Basic Training	Sortie that contains only touch-and-go type intermediate landings.
3	Shuttle	A sortie that has no intermediate landing and has a duration equal to or less than 1.5 hours.
4	Short Range Logistics	A sortie that contains no intermediate landing and has a duration greater than 1.5 hours but equal to or less than 4.5 hours.
5	Long Range Logistics	A sortie that contains no intermediate landing and has a duration greater than 4.5 hours
6	Airdrop	A sortie that contains an inflight payload drop. May contain both types of intermediate landings and high speed low-level operations of less than 30 minutes total.
7	Storm Reconnaissance or Refueling	Specialized sortie that has a duration greater than 8 hours for the weather reconnaissance aircraft or contains inflight fuel on-load or off-load.

Mission Code	Mission Type	Description
8	Combat Training	A sortie that contains 30 minutes or more of high speed-low level operations and also contains intermediate type landings which can be either touch-and-go or stop-and-go.
9	Low Level	A sortie that contains 30 minutes or more of high speed-low level operations with no intermediate landings.

Note: High speed-low level consists of operations at a height less than or equal to 2,000 above ground level and a speed greater than or equal to 190 knots equivalent air speed.

Appendix O: Calculation of the Change in C130E Fuel Consumption per Hour for the Cruise at 260, 280, and 290 Knots True Air Speed

This appendix shows the fuel flow per hour per engine extracted from the USAF C130E Performance Manual (52). The tables use 100 percent engine performance as required by MACR 55-130 (57:11-7). "Range Summary Fuel Flow" graphs were used because tabulated data was not available. The graphs are valid for an ISA day. The graphs allow for the USAF C130E modifications which increase aircraft drag and require increased fuel flow to achieve a required speed. These modifications include underwing fuel tanks, pylons, long wire HF antennas, SKE radome, European paint and walkway paint. Table XIV shows the change in fuel consumption for cruises at 260 and 280 knots TAS. Table XV shows the fuel consumption changes for crises at 290 and 280 knots TAS.

Methodology. The fuel flow per hour per engine for a TAS was extracted from the Performance Manual graphs for each weight and altitude. The data was then entered into a QUATTRO spreadsheet. The difference between the fuel flow per engine at each TAS was then calculated. Then the hourly difference in fuel consumption for the four aircraft engines was calculated. An asterisk, *, is used to indicate that fuel flow information was not available because the aircraft could not maintain the required TAS at that altitude.

Accuracy of Data. The fuel consumption graphs can be read to an accuracy of plus or minus five pounds per hour per engine. After the difference in fuel flow per engine is calculated, the accuracy could be plus or minus 10 pounds. When this fuel consumption per engine is multiplied by 4, the accuracy of the aircraft fuel flow is also multiplied by four. Therefore the accuracy of the calculated aircraft fuel consumption is plus or minus 40 pounds of fuel per hour.

Table XIV

Fuel Consumption for a USAF C130E at 260 and 280 Knots TAS

Cruise at 25,000 Feet

Aircraft Weight (lbs)	260 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 280 TAS Less Fuel for 260 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	815	915	100	400
100,000	850	940	90	360
110,000	885	975	90	360
120,000	930	1,010	80	320
130,000	980	1,055	75	300
140,000	1,040	*	–	–
150,000	*	*	–	–

Cruise at 20,000 Feet

Aircraft Weight (lbs)	260 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 280 TAS Less Fuel for 260 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	915	1,045	130	520
100,000	950	1,065	115	460
110,000	975	1,090	115	460
120,000	1,005	1,115	110	440
130,000	1,045	1,145	100	400
140,000	1,085	1,180	95	380
150,000	1,130	1,220	90	360

Cruise at 15,000 Feet

Aircraft Weight (lbs)	260 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 280 TAS less Fuel for 260 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	1,065	1,215	150	600
100,000	1,080	1,225	145	580
110,000	1,100	1,240	140	560
120,000	1,120	1,260	140	560
130,000	1,145	1,285	140	560
140,000	1,180	1,310	130	520
150,000	1,215	1,335	120	480

Table XV

Fuel Consumption for a USAF C130E at 280 and 290 Knots TAS

Cruise at 25,000 Feet				
Aircraft Weight (lbs)	290 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 290 TAS Less Fuel for 280 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	975	915	60	240
100,000	1,000	940	60	240
110,000	1,025	975	50	200
120,000	1,055	1,010	45	180
130,000	*	1,055	–	–
140,000	*	*	–	–
150,000	*	*	–	–
Cruise at 20,000 Feet				
Aircraft Weight (lbs)	290 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 290 TAS Less Fuel for 280 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	1,120	1,045	75	300
100,000	1,135	1,065	70	280
110,000	1,155	1,090	65	260
120,000	1,180	1,115	65	260
130,000	1,205	1,145	60	240
140,000	1,240	1,180	60	240
150,000	*	1,220	–	–
Cruise at 15,000 Feet				
Aircraft Weight (lbs)	290 TAS Fuel per Engine (lbs/hr)	280 TAS Fuel per Engine (lbs/hr)	Fuel for 290 TAS Less Fuel for 280 TAS (lbs/hr)	Aircraft Fuel for 4 Engines (lbs/hr)
90,000	1,300	1,215	85	340
100,000	1,310	1,225	85	340
110,000	1,315	1,240	75	300
120,000	1,345	1,260	85	340
130,000	1,365	1,285	80	320
140,000	1,385	1,310	75	300
150,000	1,410	1,335	75	300

Appendix P: Estimated Annual Savings for the Air National Guard and Air Force Reserve C130E Aircraft Using 290 Knots TAS

This appendix shows calculations of the savings which the Air National Guard (ANG) and Air Force Reserve (AFRES) could achieve by increasing the C130E cruise speed from 280 to 290 knots TAS. Cost data for 1989 has been used in this appendix.

Estimate of Annual Savings for the Air National Guard

Using the USAF mission profile analysis in Chapter IV, 52.06 percent of ANG C130E missions have the potential to be flown at cruise speeds of 290 knots TAS (13:1-15). In 1989 the ANG is planned to fly the C130E Hercules for 17,470 flying hours and 52.06 percent of this total is 9,094 hours (7). Multiplying the potential savings rate of $1.15(US) to $24.01(US) per hour times 9,094 hours results in annual savings of $12,026(US) to $218,346(US). The 0.5 percent accuracy of the mission profile data is equivalent to 87 hours for the ANG (14). Multiplying 87 hours by the potential savings rate of $1.15(US) to $24.01(US) per hour represents $100(US) to $2,089(US). Therefore, the annual savings for the ANG are estimated to be in the range of $11,926(US) to $221,084(US) if a 290 knots TAS cruise is used instead of a 280 knots TAS cruise. The $12.58(US) per flying hour midpoint of the savings times the 9,074 hours is equal to the $114,150(US) savings the ANG could expect per year at 1989 cost factors.

Estimate of Annual Savings for the Air Force Reserve

Using the USAF mission profile analysis in Chapter IV, 46.18 percent of AFRES C130E missions have the potential to be flown at cruise speeds of 290 knots TAS (13:1-15). In 1989 the AFRES is planned to fly the C130E Hercules for 21,591 flying hours and 46.18 percent of this total is 9,970 hours (7). Multiplying the potential savings rate of $1.15(US) to $24.01(US) per hour times 9,970 hours results in annual savings of $11,465(US) to $239,379(US). The 0.5 percent accuracy of the mission profile data is equivalent to 108 hours for the AFRES (14). Multiplying 108 hours by the potential savings rate of $1.15(US) to $24.01(US) per hour represents $124(US) to $2,593(US). Therefore, the annual savings for the ANG are estimated to be in the range of $11,341(US) to $241,972(US) if the cruise speed is increased from 280 to 290 knots TAS. The $12.58(US) per flying hour midpoint of the savings times the 9,970 hours is equal to the $125,422(US) savings the AFRES could expect per year at 1989 cost factors.

Note that savings have not been calculated for the C130E aircraft operating in the United States Forces in Europe because these C130E aircraft are scheduled to fly 1,500 hours in 1989 and the USAF does not maintain a unique mission profile analysis of these aircraft (6;14).

Appendix Q: Calculation of Hourly Cost Savings at 290 Knots TAS Using 1990 Maintenance Costs

This appendix contains the calculations using 1990 USAF C130E cost data of the effect on operating costs when a 290 knots TAS cruise is flown. Table XVI shows the C130E Logistics Cost Factors for 1990 in terms of 1990 dollars which were approved by the Air Force Cost Analysis Improvement Group on 23 June 1989 (7). The fuel cost for 1990 will not be specified until the price per gallon is reviewed in August 1989. The planned average Operations and Maintenance fuel consumption for 1990 is 792 gallons per hour (7). These cost factors are used to calculate the effect of a 290 knots TAS cruise on operating costs in 1990. The effect of fuel price increases on the calculated savings from a 290 knots TAS cruise is then examined.

Effect of a 290 knots TAS Cruise on Operating Costs

The effect on operating costs when the C130E is flown at speeds faster than 280 knots TAS can be demonstrated with a simple example.

Consider the cost of a 280 nautical mile task flown at 290 knots TAS. The costs for the task can be calculated as follows:

Flight time

= distance ÷ speed

= 280 nautical miles ÷ 290 knots TAS

= 0.9655 hours

Maintenance costs

= number of hours X cost per hour

= 0.9655 hours X $1,139(US) per hour

= $1,099.70(US)

The saving in maintenance costs by flying at 290 knots TAS compared to 280 knots TAS is $1,139(US) minus $1,099.70(US) which equals $39.30(US).

Table XVI

1990 Logistic Cost Factors for USAF C130E Hercules Aircraft in Terms of 1990 Dollars
Source: 7

Variable Cost Per Flying Hour	
Cost Factor	$(US)
Consumable Supplies	
Systems	119
General	105
Depot Maintenance	519
Replenishment Spares	396
Fuel	*
Total Variable Costs	$1,139*
Fixed Annual Costs Per Primary Authorized Aircraft	
Cost Factor	$(US)
Depot Maintenance	207,665
Support Equipment	19,361
Total Fixed Costs	$227,026

Note. * indicates that the fuel price per gallon for 1990 is under review.

Sensitivity of USAF Operating Costs to Fuel Prices in 1990

Using 1990 maintenance costs, the savings for the USAF in maintenance costs by flying the C130E at 290 knots TAS were shown to be \$39.30(US) per hour before any penalty for increased fuel consumption was considered.

In the worst case, the increase in fuel consumption by flying at 290 knots was shown in Chapter IV to be 340 pounds per hour. 340 pounds is converted to 53.125 gallons by dividing by 6.4 pounds per gallon. For the \$39.30(US) decrease in maintenance cost to be equaled by the increased cost of fuel, 53.125 gallons would have to cost \$39.30(US) or a fuel price of \$0.7398(US) per gallon.

In the best case, the fuel consumption may only increase by 180 pounds per hour when the cruise speed is increased from 280 knots TAS to 290 knots TAS. 180 pounds of fuel is equivalent to 28.125 gallons. If 28.125 gallons cost \$39.30(US), the price of fuel is \$1.39(US) per gallon. Therefore, when 1990 maintenance costs are used, the 290 knots TAS cruise would continue to generate savings over a 280 knots TAS cruise on all flights if the fuel price was less than \$0.7398(US). The 290 knots TAS cruise would continue to generate savings on some flights in 1990 until the fuel price reached \$1.39(US).

Appendix R: Route Data for Computer Flight Plan Demonstration Flights

This appendix shows the departure and destination airfields used in validating the affect of higher cruise speeds on reducing total operating costs. The International Civil Aviation Organization (ICAO) for each airfield, as used for the computer flight plan, is shown. The distances between the departure and destination airfield were extracted from the computer flight plan route distance and are expressed in nautical miles. The time shown is derived from the length of time displayed on the computer flight plan from take off to destination for a C130E Hercules flying at 280 knots TAS. Six minutes has been added to the computer flight plan time to correspond to RAAF and USAF methods of recording flight time for maintenance purposes. The time is in hours and minutes.

Departure Airfield (ICAO Designator)	Destination Airfield (ICAO Designator)	Flight Distance (nautical miles)	Time (hours and minutes)
Butterworth (WMKB)	Singapore (WSAP)	347	1 25
Port Moresby (AYPY)	Townsville (ABTL)	585	2 07
Honiara (AGGH)	Kwajalein (PKWA)	1,181	4 25
Honolulu (PHNL)	Travis (KSUU)	2,147	7 56

Appendix S: MACPLAN Computer Flight Plan Parameters

This appendix lists the parameters used for each of the MACPLAN computer flight plans used in this study. Each parameter is listed in the sequence used for computer input. The "plain English" responses to the computer program inputs are then given.

Departure and Destination Airfield: ICAO designator as shown in Appendix R.

Holding/Alternate: No holding or alternate requirements were specified.

Type of Aircraft: C130E Hercules.

Estimated Time of Departure: 0000 Zulu.

Payload: As shown in Tables XVIII to XXIII.

Arrival Fuel: Standard to arrive overhead with 5,000 pounds of fuel plus 15 minutes.

Weather: No wind and an ISA day.

Route: Published jet routes were selected where available. If a jet route was not available then a direct track was used.

Profile: Instrument flight rules.

Type of Cruise: TAS as shown in Tables XVIII to XXIII.

Performance Index: Optimize fuel or Optimize time as shown in Tables XVIII to XXIII.

Operational Weight: 80,000 pounds.

Maximum Available Fuel: 62,000 pounds.

Drag Index: Plus 30.

Appendix T: Analysis of MACPLAN Demonstration Flights

This appendix shows the analysis of the MACPLAN flight plans which were used in Section 2 of Chapter V to demonstrate that increasing the USAF C130E cruise speed could lead to a reduction in operating costs. The analysis includes each flight plan route listed in Appendix R and variations of payload between 1,000 pounds and 38,000 pounds. The classification of flights as shuttle, short range logistics and long range logistics is in accordance with the mission profile analysis in Appendix N.

a. Shuttle with 1,000 Pounds of Payload. The short range shuttle was flight planned over a distance of 324 nautical miles to give a flight time of 80 minutes. The first group of five flight plans used a payload of 1,000 pounds for a comparison of the operating cost when flying at 260, 280, and 290 knots TAS. The 280 and 290 cruise options were each calculated using the computer fuel optimization and the time optimization. The variable operating cost of the 280 knots TAS fuel optimized cruise was $1,941.47(US). Each of the different types of cruise was compared against the 280 TAS fuel optimized cruise as this is the current method used by MAC. The cheapest operating cost was achieved using the 290 knots fuel optimized cruise at $1,919.69(US). The difference between the costs of $21.78(US) is equivalent to a saving of $16.75(US) per hour based on the duration of the 290 knots cruise. The 280 knots TAS time optimized flight and the 290 knots TAS fuel optimized flight were both 78 minutes in duration but the time optimized flight required over 400 pounds more fuel and therefore costs more. The most expensive form of cruise of all the flights is the 260 knots cruise. The 260 knots cruise uses 200 pounds less fuel than any of the other cruise techniques but the flight takes 4 minutes longer. As a result the 260 knots TAS cruise is $56.24(US) more expensive than the 280 knots cruise. The 260 knots cruise therefore costs $40.17(US) per hour more than the 280 knots cruise. The consolidated results of these flight plans are shown on Table XVII.

Table XVII

<u>Shuttle Flight Over 324 Nautical Miles with 1,000 Pounds Payload</u>

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	80	5,709	1,941.47	-	-
280	time	78	6,249	1,958.01	-16.54	-12.72
290	fuel	78	5,847	1,919.69	21.78	16.75
290	time	76	6,424	1,939.75	1.72	1.36
260	fuel	84	5,566	1,997.71	-56.24	-40.17

b. <u>Shuttle with 38,000 Pounds of Payload</u>. The 290 knots TAS fuel optimized cruise is the cheapest cruise technique of the five different cruises examined for a shuttle flight of 324 nautical miles with 38,000 pounds of payload. This cruise technique is $23.88(US) cheaper than the comparable 280 knots cruise and this equates to savings of $17.26(US) per hour. The time optimized flight at 280 knots, and the slow 260 knots TAS are respectively $8.89(US) per hour and $21.40(US) per hour more expensive than the 280 knots TAS fuel optimized cruise. The 290 knots TAS time optimized cruise offers savings of $12.93(US) per hour over the 280 knots fuel optimized cruise; however, the high fuel consumption raises the price above the 290 knots fuel optimized cruise. Table XVIII displays the results of the cost analysis of these flight plans.

Table XVIII

Shuttle Flight Over 324 Nautical Miles
with 38,000 Pounds Payload

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	85	6,673	2,120.69	-	-
280	time	78	8,077	2,132.24	-11.55	-8.89
290	fuel	83	6,789	2,096.81	23.88	17.26
290	time	77	7,965	2,104.1	16.59	12.93
260	fuel	87	6,632	2,151.71	-31.03	-21.40

c. Short Range Logistics with 1000 Pounds Payload. A short range logistics flight over 586 nautical miles was then examined. Again the 290 knots TAS fuel optimized flight was cheaper than the comparable 280 knots cruise.

The savings resulting from the 290 knots TAS cruise equate to $19.22(US) per hour. The time optimization function in MACPLAN is defined in the computer program after the cruise technique is selected. In this series of flight plans the time optimization is 3 or 4 minutes faster than the fuel optimization. However, the 280 knots time optimization requires 4,000 pounds more fuel. As a result, the 280 knots time optimized cruise costs $140.86(US) per hour more than the 280 knots fuel optimized cruise. The 290 knots fuel optimized cruise takes 133 minutes, the same as the 280 knots time optimized cruise, but the 290 knots cruise consumes 3,723 pounds less fuel. The 290 fuel optimized cruise therefore is $354.85(US) ($3,584.24 minus $3,229.39) cheaper than the 280 knots time optimized cruise. Table XIX summarizes these results.

Table XIX

Short Range Logistics Flight Over 586 Nautical Miles with 1,000 Pounds Payload

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	137	9,223	3,272.00	-	-
280	time	133	13,232	3,584.24	-312.24	-140.86
290	fuel	133	9,509	3,229.39	42.61	19.22
290	time	130	11,045	3,323.39	-51.39	-23.72

d. Short Range Logistics with 38,000 Pounds Payload. The short range logistics flights over 586 nautical miles with 38,000 pounds of payload showed that the 280 knots fuel optimized cruise was more expensive than any of the other types of cruise technique. Unlike the 1,000 payload situation, the time optimization with 38,000 pounds of payload, planned the aircraft to climb enroute, and the resultant fuel consumptions are not very different from the fuel optimized cruise. The 290 knots fuel optimized cruise offers savings of $17.24(US) per hour and the 290 knots time optimized cruise offers savings of $30.16(US). The results of this analysis are shown in Table XX.

Table XX

<u>Short Range Logistics Flight Over 586 Nautical Miles with 38,000 Pounds Payload</u>

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	142	10,772	3,506.97	-	-
280	time	136	11,345	3,456.79	50.19	22.14
290	fuel	138	11,089	3,467.32	39.65	17.24
290	time	133	11,720	3,440.13	66.84	30.16

e. <u>Medium Range Logistics with 1,000 Pounds of Payload</u>. Medium range flights were planned over 1,181 nautical miles. At 280 knots TAS this distance requires a flight time of 4 hours 25 minutes which approximates the mission profile boundary of 4.5 hours. The 290 knots TAS fuel optimized cruise is once again the minimum cost technique of the four options considered. Savings of $22.86(US) per hour result in savings of $97.53(US) for this flight. The 280 knots cruise optimizing time consumed 25,563 pounds of fuel compared to 17,412 pounds for the 280 fuel optimizing cruise resulting in negative savings of $162.53(US) per hour. This remarkable difference is the result of the computer planning for the aircraft to fly at 9,000 feet. The 290 knots time optimizing cruise climbed enroute from 17,000 feet to 19,000 feet and finally to 21,000 feet. The 290 knots TAS time optimizing cruise is $18.98(US) more expensive than the current normal MAC C130E cruise. The 280 knots TAS time optimizing cruise, flying at 9,000 feet and consuming over 5,000 pounds more fuel than the 290 knots time optimizing cruise, appears to be an anomaly in the method that the computer is programmed. This apparent short coming in MACPLAN was brought to the attention of Lockheed programmers and has not yet been resolved. The summary of data for these flight plans is shown in Table XXI.

f. <u>Medium Range Logistics with 38,000 Pounds of Payload</u>. The familiar pattern of the 290 knots TAS fuel optimized cruise being less expensive than the comparable 280 knots TAS cruise is repeated for the medium range logistics task carrying 38,000 pounds of payload over 1,181 nautical miles. The savings of $12.85(US) per hour are reduced from the savings of $22.86(US) when the aircraft had only 1,000

Table XXI

<u>Medium Range Logistics Over 1,181 Nautical Miles with 1,000 Pounds of Payload</u>

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	265	17,412	6,288.25	-	-
280	time	261	25,563	6,995.27	-707.03	-162.53
290	fuel	256	18,038	6,190.71	97.53	22.86
290	time	254	20,271	6,368.61	-80.37	-18.98

pounds of payload. This effect can be predicted from the C130E Performance Manual. The time optimized cruises at 280 knots suffers from a cruise altitude of 11,000 feet and is $74.65(US) more expensive than the 280 knots time optimized cruise. Extracts from the medium range logistics flight plans for flights with 38,000 pounds of payload are summarized on Table XXII.

Table XXII

<u>Medium Range Logistics Over 1,181 Nautical Miles with 38,000 Pounds of Payload</u>

Cruise Speed (TAS)	Optimize	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	fuel	273	20,667	6,738.22	-	-
280	time	262	26,103	7,064.21	-325.99	-74.65
290	fuel	266	21,352	6,681.25	56.98	12.85
290	time	256	23,661	6,726.66	11.57	2.71

g. Long Range Logistics. Long range logistics flights were planned over 2,157 nautical miles with varying payloads. All of the flight plans were planned to optimize fuel because of the trend in the short and medium range flights for the time optimizing cruise to not offer significant savings over the 280 knots TAS cruise. The payload was restricted to 25,000 pounds because of limits on the take off weight of 155,000. Analysis of the flight plan data shows that regardless of aircraft weight, the 290 knots TAS cruise has lower variable costs than the 280 knots TAS cruise. As the aircraft take off weight is increased by increasing the payload and fuel, the savings which result from the 290 knots TAS cruise decrease from $17.74(US) per hour to $13.84(US) per hour. The data extracted from the long range flight plans is displayed in Table XXIII.

Table XXIII

Long Range Logistics Over 2,157 Nautical Miles
(All Flight Plans are Fuel Optimized with Varying Payload)

Cruise Speed (TAS)	Payload (lbs)	Flight Time (mins)	Fuel Used (lbs)	Cost ($US)	Saving ($US)	Saving per Hour ($US)
280	1,000	476	31,398	11,306.76	-	-
280	10,000	478	32,462	11,443.10	-	-
280	20,000	481	34,264	11,667.25	-	-
280	25,000	482	35,427	11,795.57	-	-
290	1,000	461	32,717	11,170.47	136.28	17.74
290	10,000	463	33,867	11,315.02	128.09	16.60
290	20,000	467	35,663	11,556.06	111.19	14.29
290	25,000	470	36,489	11,687.19	108.38	13.84

Appendix U: Calculation of the Saving in Maintenance Costs for a USAF C130E Flown at Speeds of 295 and 300 Knots TAS

This appendix shows the calculations of the savings in variable maintenance costs for a USAF C130E when flown at speeds of 295 and 300 knots TAS. The calculations use a 1989 variable maintenance cost of $1,048(US) per flying hour and a fuel price of $0.61(US) per gallon. Note that these savings should then be considered in terms of the increase in fuel costs required to achieve the higher TAS.

a. Calculation of Cost Savings at 295 Knots TAS. Consider the cost of a 280 nautical mile task flown at 295 knots TAS. The costs for the task can be calculated as follows:

Flight time

= distance ÷ speed

= 280 nautical miles ÷ 295 knots TAS

= 0.9492 hours

Maintenance costs

= number of hours X cost per hour

= 0.9492 hours X $1,048(US) per hour

= $994.76(US)

The saving in maintenance costs by flying at 295 knots TAS compared to 280 knots TAS is $1,048(US) minus $994.76(US) which equals $53.24(US). Flying the C130E at a TAS of 295 knots saves $53.24(US) in variable maintenance costs when compared to the same flight flown at 280 knots TAS.

b. <u>Calculation of Cost Savings at 300 Knots TAS</u>. Consider the cost of a 280 nautical mile task flown at 300 knots TAS. The costs for the task can be calculated as follows:

Flight time

= distance ÷ speed

= 280 nautical miles ÷ 300 knots TAS

= 0.9333 hours

Maintenance costs

= number of hours X cost per hour

= 0.9333 hours X $1,048(US) per hour

= $978.10(US)

The saving in maintenance costs by flying at 300 knots TAS compared to 280 knots TAS is $1,048(US) minus $978.10(US) which equals $69.90(US). Flying the C130E at a TAS of 300 knots saves $69.90(US) in variable maintenance costs when compared to the same flight flown at 280 knots TAS.

Appendix V: Calculation of Increased Fuel Consumption for 295 knots and 300 knots TAS Cruises to Break Even

This appendix shows the calculations of the increase in fuel consumption per hour which is available for the variable maintenance savings to be balanced exactly by increased fuel costs when cruising at 295 and 300 knots TAS. The calculations use a fuel price of $0.61(US) per gallon and the variable maintenance savings, of $53.24(US) for a 295 knots TAS cruise, and $69.90(US) for a 300 knots TAS cruise, as calculated in Appendix Q.

a. Cruising at 295 Knots TAS. If the cost of flying at 295 knots TAS is to be the same as flying at 280 knots TAS, then the decreased maintenance cost must be equaled by a increase in fuel costs. The additional quantity of fuel which must be consumed by flying at 295 knots TAS can be found as follows:

Increased fuel consumption to break even on costs

= maintenance cost saving

= $53.24(US)

= $53.24(US) ÷ $0.61(US) per gallon

= 87.28 gallons

= 87.28 gallons X 6.4 pounds per gallon

= 558.59 pounds

Since the flight at 295 knots took 0.9492 hours the fuel savings required to break even per hour

= 558.59 pounds ÷ 0.9492 hours

= 588 pounds per hour

Therefore a cruise at 295 knots TAS can consume 588 pounds per hour more fuel and the total variable cost of the flight will still be the same as a flight flown at 280 knots TAS. If the fuel consumption increase is less than 588 pounds per hour, then a 285 knots TAS cruise will result in net savings to the USAF for costs calculated in 1989.

b. Cruising at 300 Knots TAS. If the cost of flying at 300 knots TAS is to be the same as flying at 280 knots TAS, then the decreased maintenance cost must be equaled by a increase in fuel costs. The additional quantity of fuel which must be consumed by flying at 300 knots TAS can be found as follows:

Increased fuel consumption to break even on costs

= maintenance cost saving

= \$69.90(US)

= \$69.90(US) ÷ \$0.61 per gallon

= 114.59 gallons

= 114.59 gallons X 6.4 pounds per gallon

= 733.38 pounds

Since the flight at 300 knots took 0.9333 hours the fuel savings required to break even per hour

= 733.38 pounds ÷ 0.9333 hours

= 785 pounds per hour

Therefore a cruise at 300 knots TAS can consume 785 pounds per hour more fuel and the total variable cost of the flight will still be the same as a flight flown at 280 knots TAS. When the increase in fuel consumption is less than 785 pounds per hour, a 300 knots TAS cruise would result in net savings to the USAF for 1989 costs.

Appendix W: Calculation of Aircraft Operating Costs Using Flight Planning Computers

This appendix uses the methodology within this study to calculate the aircraft operating costs for a flight. The calculations could be used by aircrews of USAF aircraft which utilize computer flight planning facilities. The appendix specifies the outputs required from the computer flight planning system, the inputs required from the Air Force Cost Center and the operating cost calculations.

Inputs Required from Current Computer Flight Plan System

The inputs required from the computer flight plan system are as follows:

Flight time in minutes = FT

Fuel Consumption in pounds per hour = FU

Inputs from Air Force Cost Center

The inputs required from the Air Force Cost Center are as follows:

Current fuel cost = FC

Current variable maintenance costs from AFR 173-13 = MC

The variable maintenance costs listed in AFR 173-13 are those which vary per flying hour. These are Flying Hour Consumable Supplies (Systems and General), Variable Depot Maintenance, and Replenishment Spares. Note that these costs should be the latest available cost data expressed in terms of the current year dollars. These data are available direct from the Air Force Cost Center.

Operating Cost Equation

The variable direct operating costs for any flight is the sum of the fuel cost and the maintenance cost. The cost of a flight is therefore calcu'ated as follows:

Cost of a Flight

= Fuel Cost + Maintenance Cost

Fuel cost

= Fuel used in pounds X 6.4 X Fuel cost per gallon

= FU X 6.4 X FC

where

6.4 pounds of fuel = 1 gallon

Corrected Flight Time

The flight time calculated in the computer flight plan is corrected by adding six minutes to account for the USAF technique of recording flight times.

Corrected Flight Time

= Flight time in minutes + 6 minutes

= CFT

Maintenance Cost

= [(Corrected Flight Time in minutes) ÷ 60] X (Variable Maintenance Cost per hour)

= [CFT ÷ 60] X MC

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Vita

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In 1974 he completed a Bachelor of Science degree, majoring in mathematics and physics, at Melbourne University and the Royal Australian Air Force (RAAF) Academy. He was commissioned as a Flying Officer in 1975 after completing a Graduate Diploma of Military Aviation. After graduating from pilot training, he was posted for flying duties in C130E Hercules aircraft at 37 Squadron RAAF. In 1980 he qualified as a flying instructor and instructed at the RAAF's advanced pilot training school. In 1982 he began a tour as a flying instructor on exchange with the Royal New Zealand Air Force. He returned to 37 Squadron in 1984 for a further four years flying C130E Hercules aircraft. During this tour he held the executive appointments of Training Flight Commander, Operations Flight Commander and Executive Officer. In 1988 he entered the United States Air Force Institute of Technology to study for a Master of Science degree majoring in Logistics Management. Following graduation he returns to the Department of Defence (Air Office) in Canberra, Australia.

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Abstract

The purpose of this research study was to examine a proposal to reduce C130E Hercules operating costs in the Royal Australian Air Force (RAAF) and the United States Air Force (USAF) by increasing cruise speeds. The current fuel conservation policies in the RAAF and USAF do not consider the effect of the policy on aircraft operating costs.

RAAF C130E cost data were found to be invalid. The study quantified major differences in the depot servicing, contract servicing, and in-house servicing for RAAF C130E and C130H Hercules aircraft. The study suggests that the RAAF should improve the accuracy of C130E cost data to allow a valid assessment of the operating costs over the aircraft life cycle.

USAF C130E cost data was readily divided into fixed and variable costs. The variable maintenance costs were found to be more than double the hourly fuel costs. Flight Manual data and mission profile data were used to show that the USAF could save $94,613 to $1,979,227(US) in 1989 by flying selected missions at 290 knots instead of 280 knots true airspeed (TAS). The midpoint of the calculated savings is $12.58(US) per flying hour which represents USAF savings of $1,027,017(US) per year for 1989 cost factors.

The Lockheed MACPLAN computer flight plan system was used to verify the theoretical calculations. Savings of $5.17(US) to $15.18(US) per flying hour were demonstrated using 290 knots TAS over short and long range missions with varying payloads. The sensitivity of the calculated savings to changes in fuel and maintenance prices was also examined.

The study concludes that USAF C130E operating costs can be reduced by increasing cruise speeds. The study recommends that the USAF introduce 290 knots TAS cruise procedures immediately because of the reduction in operating costs and because there are no implementation costs.